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AN/TPS-1G INDICATOR SYSTEM

MILITANT

U.S. ARMY AIR DEFENSE SCHOOL

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CONTENTS

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CHAPTER 1

INTRODUCTION

1. PURPOSE AND SCOPE

a. Purpose. The purpose of this instructional text is to provide a source of reference material for the technical maintenance of the AN/TPS-1G.

b. Scope. This text covers the technical operation of the indicator unit.

2. REFERENCES

The AN/TPS-1G Troubleshooting Manual is a basic reference for this text.

CHAPTER 2

BLOCK DIAGRAM OF THE INDICATOR SYSTEM, CATHODE-RAY TUBE OPERATION

Section I. INTRODUCTION

3. FUNCTIONS

The range-azimuth indicator unit (fig 1) provides a means of determining visually the range and azimuth of a target by two cathode-ray tubes on which target intelligence is displayed. All components necessary for developing the sweep voltages, range markers, strobe marker, and high operating voltages for the oscilloscopes are contained in the indicator unit. In addition, the unit contains the mixer stages for mixing normal or gated MTI radar video signals and IFF video signals displayed by the scopes. The two scopes used for presentation of data are the A-scope, which displays range only and is usually referred to as the range scope, and the plan position indicator (PPI), which indicates both range and azimuth. The trigger for the sweep and range marker circuits is a positive pulse from the pulse transformer that is located in the transmitter. Since the trigger originates at the same time the magnetron fires, or at radar time zero, accurate ranging of targets can be obtained. In reference to range, nautical miles are the units of measure used with the AN/TPS-1G, and "miles" in the text will always be read "nautical miles." Also, when referring to scope presentation, the view of the screen is from the outside front of the scope as the operator sees it.

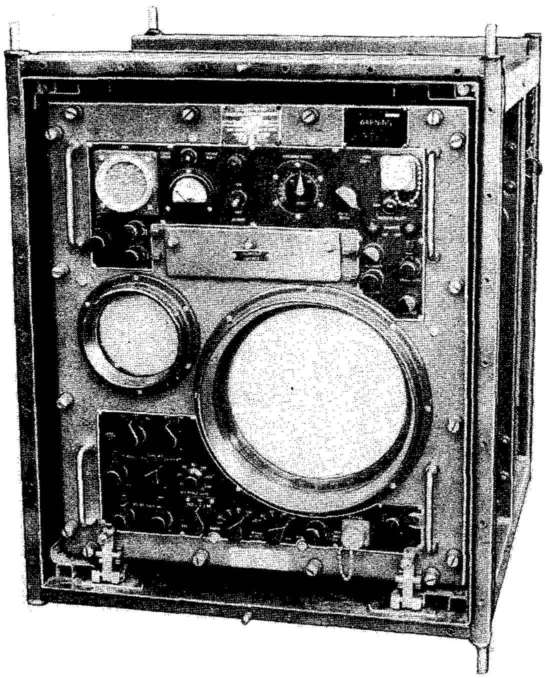

Figure 1. Indicator.

4. A-SCOPE

a. The A-scope is commonly referred to as the range scope because only slant range is displayed upon its face. It is a 5-inch, horizontal-sweep oscilloscope that uses electrostatic deflection (fig 2(1)). Electrostatic deflection provides a sweep that is the result of the movement of a stream of electrons across the face of the scope from left to right. At the instant the magnetron fires, the trigger from the pulse transformer initiates sweep circuits that start the sweep across the scope face at a speed that will give accurate ranging to the received target returns. As they are deflected across the face of the scope, the stream of electrons causes a horizontal line to appear due to the high persistency of the scope face. The return of the electron beam to the left side of the scope cannot be seen because a blanking voltage is applied to the control grid of the A-scope. The beginning of the sweep, which is to the left, represents zero range. The entire baseline can be changed to represent 20, 40, 80, or 160 nautical miles. In the EXPAND position, the sweep deflection originates from the strobe marker. This sweep deflection is a constant 10-nautical-mile display covering the entire sweep of the A-scope. This display can be adjusted by the strobe position to present any 10-mile section from 10 to 160 miles as displayed on the PPI. Since only 10 miles of range are shown on the A-scope, a range strobe displayed on the PPI is used to determine the position of this 10-mile range. The range strobe represents the beginning of the 10-mile sweep displayed on the A-scope; that is, if the strobe appears at 75 miles on the PPI, the sweep on the A-scope will start at 75 miles and extend to 85 miles. The left-to-right deflection of the sweep is dependent upon two horizontal deflection plates within the tube.

b. The positive range markers and video signals are applied to the top vertical deflection plate and appear as positive pips on the horizontal sweep. The range markers appear at 5-mile intervals on the EXPAND, 20 and 40 nautical mile sweeps, and at 25-mile intervals on the 80 and 160 nautical mile sweeps. The range to a target can be determined by comparing the position of the target pip to the range markers. There is no way of determining azimuth from this type of presentation even though the returns that appear on the baseline at any one time do represent the azimuth of the antenna.

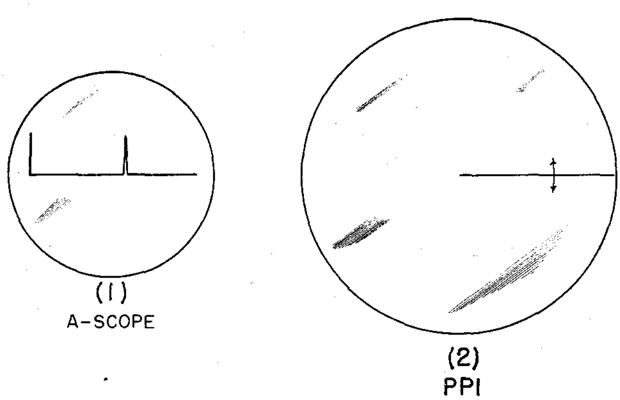

Figure 2. A-scope and PPI presentation.

5. PPI

The PPI (fig 2(2)) is a 10-inch cathode-ray tube that employs electromagnetic deflection of its sweep. The sweep starts at the center of the scope in the form of a radial line that increases in range as the sweep moves outward from the center. A deflection coil that produces a magnetic field enables the electron stream to move from the center to the outside of the screen. The sweep ranges of the baseline are 20, 40, 80, or 160 nautical miles. The deflection coil is rotated around the body of the tube in synchronism with the antenna rotation, therefore the radial baseline will rotate. The position of the radial sweep at any instant of time indicates the exact azimuth at which the antenna is pointed and azimuth resolution is made possible. Target video returns, range strobe marker, and range markers appear on the radial sweep and are indicated on the scope face by intensity modulation that persists for a few seconds enabling better video viewing. Range markers are spaced at 5 miles for the 20- and 40-mile sweeps and 25 miles for the 80- and 160-mile sweeps. The strobe marker, which appears as a dot on the radial sweep, is variable in range from 10 to 160 nautical miles. It is used to select any 10-mile interval of range that is to be displayed across the full width of the A-scope screen.

Section II. BLOCK DIAGRAM OF THE INDICATOR

6. A-SCOPE SWEEP CHANNEL

a. Sweep multivibrator V622. The A-scope sweep multivibrator V622 is a start-stop multivibrator that is triggered by the positive trigger from the pulse transformer (fig 3(1)) when the A-scope range selector switch S609A is set for 20, 40, 80, or 160 nautical miles. It is triggered by a positive trigger from the strobe multivibrator (fig 3(18)) when the RANGE SELECTOR switch S609A is in the EXPAND position. The output of V622 is two square waves, 180° out of phase, with the trailing edges variable in time. The variable trailing edges determine the length of the output square waves. The square waves act as gates, and their time duration determines the length of the sweeps. The negative output square wave (fig 3(3)) will produce a 10-, 20-, 40-, 80-, or 160-mile sweep depending upon its duration. The positive output square wave from the B-section (fig 3(2)) is applied to the control grid of the A-scope for unblanking the scope. From the A-section of the multivibrator, the negative square wave is applied to the sweep generator V623.

b. DC restorer V604B. The dc restorer V604B maintains the same charge on the selected range condensers for each time multivibrator V622 is triggered. This insures constant gate sweep lengths and stability of the sweep circuits for successive sweeps.

c. Sweep generator V623. The negative square wave from the sweep multivibrator is the input to the control grid of the sweep generator V623. It holds the stage at cutoff for the duration of the negative gate. While the tube is cut off, the output of the stage becomes a positive sawtooth voltage waveform of the proper pattern for producing deflection on the scope (fig 3(4)).

d. Sweep-inverter amplifier V624. The positive-going sawtooth voltage signal from the sweep generator is applied to a push-pull amplifier V624. This stage provides two sawtooth outputs 180° out of phase (figs 3(5) and 3(6)). The negative output from the A-section is

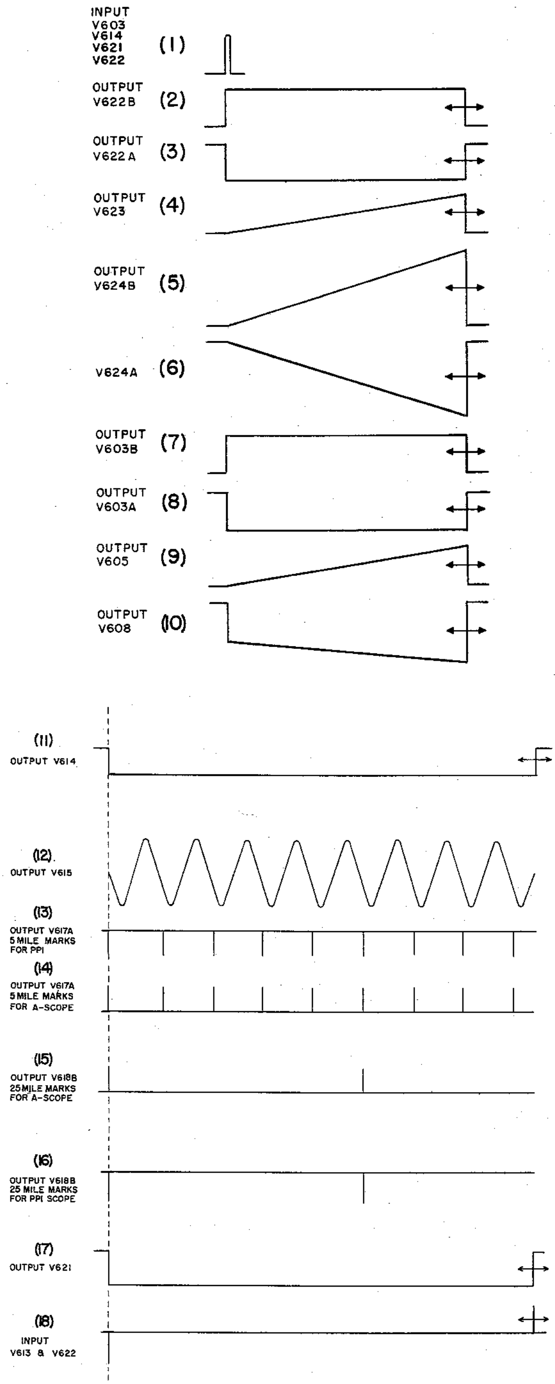

Figure 3. Indicator waveforms.

applied to the left horizontal deflection plate; the positive output from the B-section to the right horizontal deflection plate of A-scope V625. This application gives a push-pull deflection to the electron beam of the range scope to keep the deflection sensitivity constant over the the entire range.

7. PPI SWEEP CHANNEL

a. Sweep multivibrator V603. The PPI sweep multivibrator V603 is a start-stop multivibrator that is always triggered by the same positive pulse from the pulse transformer that triggered the A-scope sweep channel (fig 3(1)). Its output, after being triggered, is two square waves that are 180° out of phase with trailing edges, and variable in time, to represent the sweep lengths of 20, 40, 80, or 160 nautical miles. The negative square wave from the A-section (fig 3(8)) is applied to the control grid of the PPI sweep generator V605; the positive square wave from the B-section (fig 3(7)) is applied to the PPI control grid to unblank the scope.

b. DC restorer V604A. The dc restorer V604A maintains the same charge on the selected range condensers for each time the multivibrator V603 is triggered. This insures constant gate sweep lengths and stability of the sweep circuits for successive sweeps.

c. Sweep generator V605. The sweep generator V605 is cut off by the negative square wave output from the sweep multivibrator. During the time that the tube is cut off, the stage produces at its output a positive-going sawtooth voltage (fig 3(9)).

d. Sweep amplifier V606. The positive-going sawtooth voltage from the sweep generator is applied to the voltage amplifier V606, which contains two stages of amplification. The output of V606 is a positive-going voltage that is applied to the power amplifier V608.

e. Power sweep amplifier V608. The sweep amplifier V608 is a power amplifier with its output connected to the deflection coil of the PPI. The positive signal from V606 is applied to the control grid of the power amplifier, and a negative feedback circuit that modifies the sawtooth output of V605 so that it is changed to a trapezoidal form when applied to the grid of V608, is connected between V608 and V606. The step in the negative trapezoidal voltage (fig 3(10)) applied to the deflection coil is necessary so that a sawtooth current due to the overcoming of the inductance in the coil will result. The sawtooth of current through the deflection coil produces the radial baseline from the center of the PPI.

f. DC restorer V607A. The dc restorer V607A holds the grid of the power sweep amplifier V608 at a cutoff potential. The trapezoidal voltage applied at the grid overrides this bias bringing V608 out of cutoff and producing a sawtooth of current through V608 and the deflection coil. At all other times, the cutoff bias prevents any current conduction or fields in the deflection coil; thus insuring that the PPI sweep will always begin at the center of the screen.

8. RANGE MARKER CHANNEL

a. Range marker multivibrator V614. Multivibrator V614 is triggered by the same positive pulse from the pulse transformer that is used to trigger the sweep channels (fig 3(1)). The

output of the marker gate generator is a negative-going square wave with a width (gate length) that is variable in time to make sure that a sufficient number of range marks are produced for all ranges (fig 3(11)).

b. Range marker oscillator V615. The negative square wave from the marker multivibrator is applied as a gate to the marker oscillator V615 and activates the oscillator. When the tube is cut off by the gate, oscillations are produced at a frequency slightly over 16 kc so that the resultant range marks will represent 5-mile intervals (fig 3(12)). With the negative half-cycles of each oscillation being used, the first marker occurs at the same time that the magnetron fires, and sustained oscillations continue for sweep ranges up to 160 nautical miles.

c. Range marker amplifier V616A. The range marker amplifier V616 receives the output oscillations from the marker oscillator V615. It steepens the leading edges of the oscillations before they are applied to the 5-mile blocking oscillator V616B and V617A.

d. 5-mile blocking oscillator V616B and V617A. The positive and negative oscillations are the input to the grid of V616B; the output is positive pulses that are coupled to V617A through transformer action. The pulses are shaped and amplified by the action of V617A to produce range markers at 5-mile intervals, which are used with the 20- and 40-mile sweeps. There are two positive outputs and one negative output with 5-mile intervals between pulses from the stage of V617A. The outputs are applied to the following:

(1) A-scope video and marker mixer V619 (fig 3(14)).

(2) PPI video and marker mixer V602 (fig 3(13)).

(3) 25-mile blocking oscillator driver, V617B (fig 3(14)).

e. 25-mile blocking oscillator V617B and V618B. The 25-mile blocking oscillator V617B and V618B is a 5-to-1 countdown circuit that is triggered by an output from the 5-mile blocking oscillator. The first input trigger, a 5-mile range marker, will give an output from the 25-mile blocking oscillator, but the next output will occur when the fifth 5-mile marker is received (fig 3(15) and (16)). The oscillator is held cut off during the intervening markers between the first and fifth markers by a negative charge which is formed in the grid circuit of V618B. The negative charge leaks off slowly and remains negative long enough to hold V618B cut off until each fifth 5-mile marker is applied. With this countdown, 25-mile markers which are positive pulses at the cathode (fig 2(15)) and are used for the 80- and 160-mile sweeps when displayed on the A-scope, are produced by V618B. The output to the PPI is negative off the plate (fig 3(16)) of V618B.

f. DC restorer V618A. The dc restorer V618A clamps V618B at a cutoff potential so that introduction of each fifth trigger from the 5-mile blocking oscillator is necessary before V618B will operate. After conduction of V618B and production of a 25-mile range mark, the dc restorer is cut off by a negative charge on the grid of the oscillator. With the dc restorer cut off, a long time-constant discharge path is in the grid circuit so that no further 5-mile trigger inputs will induce conduction. This condition will last until the charge has leaked off or about the time of the fifth input trigger.

9. STROBE CHANNEL

a. Strobe multivibrator V621. The strobe multivibrator V621 is a start-stop multivibrator triggered by the trigger pulse from the pulse transformer (fig 3(1)). The output is a negative square wave with a trailing edge that is varied in time by the time constants of the multivibrator (fig 3(17)). The negative square wave is peaked with the positive peak corresponding to the previously variable trailing edge. Therefore, the positive peak is variable in time. The output of the strobe multivibrator is always applied to the PPI video channel through the strobe blocking oscillator V613. When the SWEEP SELECTOR S609A is in the EXPAND position, the peaked positive output is also applied to the A-scope sweep multivibrator V622 as a trigger. The sweep of the A-scope is started at a time corresponding to the variable positive peak that also represents the position of the range strobe marker on the PPI (fig 3(18)).

b. Strobe blocking oscillator V613. The negative and positive pulses from the strobe multivibrator are the input to the strobe blocking oscillator V613. The fixed negative peaks have no effect on the blocking oscillator because it is cut off in the quiescent state; however, the variable positive peak causes V613 to conduct. The negative strobe marker output of V613 is fed into IFF-STROBE mixer V601. For each sweep that is produced by the PPI sweep channel, one strobe marker is generated and displayed upon the sweep.

c. IFF-STROBE mixer V601. The IFF-STROBE mixer V601 has the positive IFF video and the negative strobe marker as its inputs. The stage mixes the signals obtaining a negative polarity at the output so the signals can be applied directly to the cathode of the PPI.

10. VIDEO CHANNEL

The video channel is covered in detail in the AN/TPS-1G receiver system text. For further reference other than a block diagram discussion, consult the receiver text, ST 44-188-4G.

a. Video amplifiers V611 and V612A. The positive video pulses from the signal comparator are amplified by the first video amplifier in the indicator V611. The positive output of V611 is coupled to a cathode follower V612A. From the cathode follower, positive video pulses are applied to the PPI video and range marker mixer V602 and the A-scope video amplifier V619.

b. A-scope video amplifiers V619 and V612B. The A-scope video amplifier has two inputs, positive radar video and range marks. The output of V619 is a negative pulse for each range marker or video signal, with the output applied to V612B. V612B in turn amplifies and inverts the signals so that the output is positive in polarity. From the amplifier the positive video and markers are applied to the top deflection plate of the range scope V625.

c. PPI video circuit V601 and V602. The PPI video circuit is a two-stage mixer, V601 acting as the IFF video and strobe mark mixer and V602 acting as radar video and range mark mixer. The two tubes have a common plate load and a common output so that all four types of signals may be combined. Regardless of whether the video originates at

V601 or V602, the polarity at the common output will be negative. The negative output of V601 and V602 is the input to the PPI cathode where it produces intensity modulation of the PPI.

Section III. A-SCOPE OPERATION

11. GENERAL

a. The A-scan radar display (fig 4) presents range information of detected target signals. It uses a 5CP1A electrostatic oscilloscope with a 5-inch horizontal sweep across the scope face. The sweep length is calibrated in nautical miles for raning of the targets from the radar antenna. Target echo signals are applied to the scope in such a manner that a deflection modulation is obtained on the horizontal baseline. The degree of the positive deflection, pip size, also provides information about the size, shape, and nature of the detected target. The cutaway view of the A-scope (fig 4) should be followed when reading the A-scope discussion.

b. The electrons are emitted from an indirectly heated cathode surface and formed into a beam by passage through an aperture at the end of a cylinder that is placed over the cathode to serve as the control grid. The electrons emitted from the cathode pass between the focusing anodes. The first anode has a high negative potential in respect to ground, but is positive in respect to the cathode. The second anode is at a positive potential in respect to both ground and cathode. As the electrons pass through the strong electrostatic field between the two anodes, they are focused into a converging beam which comes to a point on the scope face. The beam of electrons next passes between two vertical deflection plates with the video and range markers applied as positive signals to the top plate. This deflects the electrons upward whenever video signals are applied. The lower deflection plate is tied to an adjustable dc potential for vertical positioning of the baseline. The electron beam is caused to move at a horizontal linear rate by the potentials that are placed on the horizontal deflection plates. A negative sawtooth voltage is applied to the left deflection plate and at the same time a positive sawtooth voltage is applied to the right deflection plate. The sawtooth voltages begin when the transmitter fires and end after the time interval required to detect an object at the maximum or desired range of the radar system. These deflection voltages cause the beam of electrons to sweep across the screen from left to right; the negative voltage gives a push action, the positive voltage a pull action on the beam. The horizontal sweep is made to move at a linear rate with equal distances corresponding to equal time intervals after the transmitter fires. After the beam of electrons passes the horizontal deflection plates, it continues until it strikes the face of the scope. An aquadag voltage, highly positive, is placed on a coating to the rear of the screen and removes electrons caused by secondary emission.

12. MEASUREMENT OF RANGE

a. In order to measure range along the horizontal baseline on the A-scope screen and the radial sweep of the PPI screen, the electron stream is made to deflect at a linear rate to produce an accurate time base. It is known that rf energy velocity is slightly over 186,000 statute miles per second. Since 1 nautical mile is equal to 1.1516 statute miles, rf energy will travel 1 nautical mile in 6.19 microseconds. The nautical mile is used because it is more convenient for the Army and Air Force plotting systems. Because the energy must travel to a target and return to the radar, a target that is 1 nautical mile from the radar

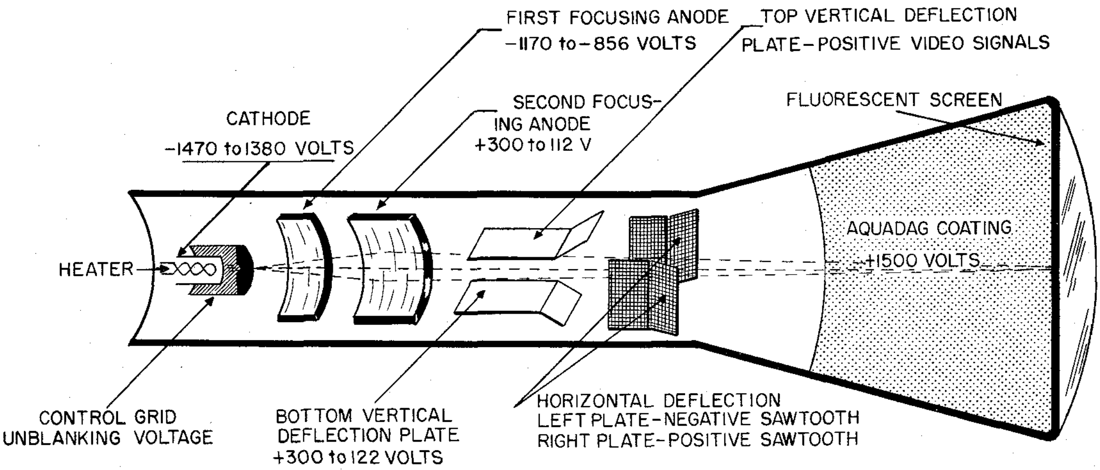

Figure 4. Cutaway view of A-scope.

will require 12.38 microseconds to detect the target after the transmitter fires. The sweep on the presentation screen must be calibrated so that under the above conditions it will have moved for 12.38 microseconds to the point on the baseline representing the time taken by the transmitted pulse to reach the target one mile away and return. If the 5-inch A-scope sweep is to represent 10, 20, 40, 80, and 160 nautical miles, it must last for the five different time durations shown below.

	Sweep Display	Sweep Duration
(1)	10 nautical miles	123.8 microseconds
(2)	20 nautical miles	247.6 microseconds
(3)	40 nautical miles	495.2 microseconds
(4)	80 nautical miles	990.4 microseconds
(5)	160 nautical miles	1,980.8 microseconds

b. It is imperative that any point on the sweep, regardless of the total sweep range, be equal in proportion to and representative of the exact time elapsed after the transmitter is fired. This requirement can be met with a sawtooth voltage whose rising amplitude causes

the sweep to move slowly and linearly from left to right. In figure 5, the sawtooth voltage waveform and the A-scope time baseline are illustrated. At point A on the sawtooth voltage, the sweep on the screen is at the extreme left. As the voltage linearly increases, the baseline is moved from A to B due to the increased voltage from A to B. Notice that for each increase in voltage, a similar step occurs along the baseline making the voltage changes from A to B, B to C, C to D, and D to E equal and corresponding to the resultant changes in the A-scope baseline. To increase the total sweep duration, there must be an increase in the elapsed time after the sweep starts as well as a decreased slope in the sawtooth voltage, but the end resultant of the maximum voltage amplitude remains the same for all sweep lengths. The total amount of sawtooth voltage that can be applied is limited to the amount that will drive the sweep to the extreme right edge of the screen. Therefore, to increase the total sweep duration from one range to another, as is actually accomplished when the sweep ranges are changed from 10, 20, 40, 80, or 160 miles, the rise rate of the sawtooth voltage must decrease so that the maximum voltage point, point E, will always remain the same. If the rise in the voltage is not linear, irregular time intervals will exist along the time base. If the total baseline in figure 5 represented 20 miles, the time base can be calibrated with range markers by placing them at points A, B, C, D, and E, each divided interval equaling 5 miles. At point E, where the voltage drops back to zero, the baseline ends, and a flyback in the sweep to the left is made very rapidly. At the beginning of the next sawtooth voltage and transmitter firing, the complete operation starts at the identical time again. The sawtooth voltage is applied to the horizontal deflection plates in order to obtain a horizontal baseline.

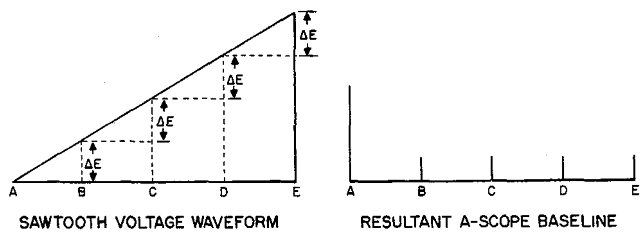

Figure 5. Generation of the A-scope baseline.

13. CATHODE CIRCUIT

The cathode, pin 2, is tied to the filaments, pins 1 and 14, to provide heating of the cathode and prevent arcing between the cathode and filament. The thermal agitation of the oxides that form the coating on the cathode results in the emission of a large quantity of electrons from the cathode surface known as the space charge. The quantity of electrons that are emitted from the cathode is varied by INTENSITY control R1693, which regulates the negative voltage potential on the cathode. This control varies the cathode voltage from the limits of approximately -1,380 volts to -1,470 volts by the use of the voltage divider network R1692 through R1698. Since the cathode is connected to the filament, the filament voltage of 6.3 volts ac rides at the same dc level as the cathode. This filament voltage is taken across the secondary windings, terminals 7 and 8 of the indicator filament transformer T605. As the cathode emits electrons, the electrons from the space charge are attracted to the fluorescent screen because of the high potential that exists toward the front of the CRT.

14. CONTROL GRID

The control grid, pin 3, is tied to the negative 1,500-volt supply through a coupling resistor R169 and to the A-scope multivibrator V622B through C661. With no positive square wave signal applied from the multivibrator, there is no voltage dropped across R1691, and the control grid is at a negative 1,500 volts. When the positive unblanking pulse from the multivibrator is applied during each sweep, this positive voltage is coupled across C661 and applied to the control grid, decreasing its bias and controlling the number of electrons in the space charge during the length of the positive gate. The more positive the grid becomes, the more electrons there will be in the electron beam. As in an ordinary vacuum tube, the charge on the grid may be made so negative in respect to the cathode that the beam current is completely eliminated by adjusting the cathode to a greater positive potential in respect to the control grid with INTENSITY control R1693.

15. FOCUSING ANODES

a. The first focusing anode, pin 5, determines the point where the electron beam will be brought into focus. The voltage on the anode is made to vary from -856 volts to -1,170 volts by the FOCUS control R1696. The focus control sets the potential on the anode; therefore, it determines the strength of the electrostatic field between the first and second anodes, which are open cylinders about the axis of the tube.

b. The second anode, pin 9, is at a variable positive potential from 112 to 300 volts, which is controlled by the ASTIGMATISM control R1689. The positive potential of the second anode should be set to equal the same potential as the average deflection plate voltage. The equal potentials eliminate the effect of electrostatic fields between the focusing anodes and the deflection plates, which would defocus the electron beam.

c. The aperture at the end of the control grid forms the electron stream into a broad beam going through the focusing anodes. The strong negative potential on the first anode and the positive potential on the second anode set up a strong electrostatic field between the anodes. Any electron going directly through the center of the anodes travels along the axis of zero electrostatic field and is directed to the center of the cathode-ray tube face. The electron paths not directly in the center of the field cross lines of force, causing them to bend so that their paths converge at a focal point with the path of the center electrons. The correcting action of the electrostatic field upon the electron path is shown in figure 6, where the electron beams converge at the scope face. Thus all the electron paths will be bent to meet the center beam at the same focal point, which must be at the face of the scope for proper

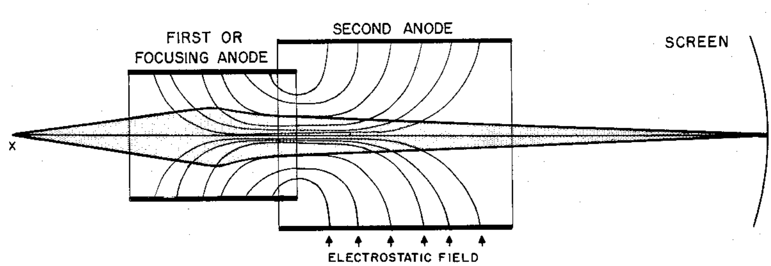

Figure 6. Effect on electron beam by the electrostatic field.

focusing. The FOCUS control R1696 is set to control the electrostatic field that determines the point of focus. If the electrostatic field is too strong, the focal point occurs nearer the anodes, putting it behind the scope face (fig 6). This is the case with the first anode at a greater negative potential than for proper focusing. If the electrostatic field is too weak, the opposite conditions of potentials and focal point will exist.

16. DEFLECTION PLATES

a. The stream of electrons, after being accelerated and focused by the first and second anodes, passes the vertical and horizontal deflection plates, respectively (fig 7). Since the deflection plates exert the same amount of deflection on all electrons, there is no effect on the focusing. The bottom vertical plate, pin 8, is connected to the VERTICAL CENTERING control R2601, which varies the positive potential on the plate from 112 to 300 volts. This voltage enables the sweep baseline to be positioned vertically at the desired point on the screen. The top vertical plate, pin 7, has the radar video and range markers applied as positive voltage signals. In the absence of the video or range markers, the electrostatic field is adjusted by the dc potential on the bottom deflection plate so the electron beam is centered at A. When either positive range markers or video is applied to the top plate, pin 7, an increased electrostatic field V_1 occurs from the bottom to the top plate perpendicular to the electron stream V_2 and causes the electrons to be deflected toward the plate with the higher positive potential, and the stream of electrons bends to cause an upward deflection of the sweep baseline toward B. The angle θ increases from 0° as the voltage of the positive signals increases from a zero reference; the resulting presentation on the screen is a positive pip. The rate of the rise and fall of the electron beam is exactly equal to the rate of the rise and fall of the video or range marker signal. The amount of deflection is proportional to the amplitude of the applied positive signal.

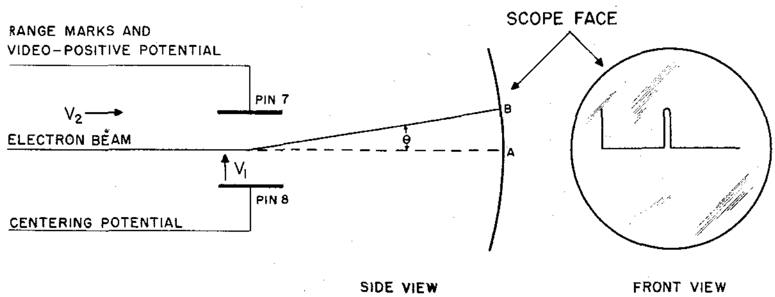

Figure 7. Vertical deflection of range markers.

b. The horizontal deflection plates are positioned vertically in the cathode-ray tube (fig 8), causing the electron beam to be deflected from left to right on the scope face. In the absence of a sawtooth voltage being applied to the deflection plates, the electrostatic field between the left deflection plate, pin 11; and the right deflection plate, pin 10, is adjusted so the electron beam is positioned at the extreme left of the screen. This horizontal positioning is a function of the HORIZONTAL CENTERING control R1687 in the A-scope sweep circuits. The A-scope sweep circuits generate two sawtooth voltages opposite in polarity but identical in starting time and amplitude. As the negative sawtooth

waveform input is applied to the left plate, pin 11, a positive sawtooth is applied to the right plate, pin 10. At points A and A_1, the electron beam is at the left of the screen, A_2. The negative voltage on the left plate and a positive voltage on the right plate give a push-pull action on the electron beam as the voltage is increased. The displacement of the electron beam is linear in time with a linear voltage change. As the voltage decreases on the left plate and increases on the right plate, the electron beam is deflected to the right due to the change in the electrostatic field. Note the position of the electron beam when the voltage is at B and B_1. The beam is at the center, B_2, of the screen with one-half the sweep voltages applied. The change in θ is equal to the change in voltage on the deflection plates. When the voltage has increased to points C and C_1, the electron beam is moved completely to the right side, C_2 of the scope face. Also, at points C and C_1, the voltage drops back to its reference potential and the beam is retraced very rapidly to the left. It should be realized that the electron beam is merely a spot on the screen, but the recurrence of the sweep, about 400 times per second, the persistency of the screen, 1 second, and the persistency of the human eye combine to give the illusion of a continuous horizontal sweep. The purpose of C659 and C660 is to balance the coupling effect between the vertical and horizontal deflection plates so that the positive signals applied to the top vertical plate will be deflected entirely vertically and there will be no horizontal deflection component in the video-range marker presentation. If C659 is misadjusted, the video-range marker presentation will lean to the horizontal.

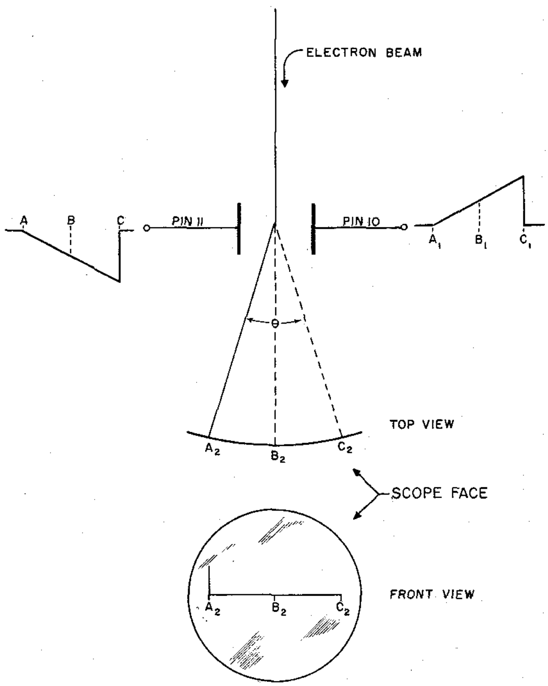

Figure 8. Horizontal deflection of the electron beam.

17. SCREEN AND AQUADAG

The face of the scope is covered with willemite, a zinc orthosilicate that exhibits fluorescence when bombarded with a high-velocity electron stream, which means that the energy received by the coating is released in the form of light energy. In the case of willemite, the light energy is in the green part of the visible light spectrum, so this mineral exhibits the intelligence imparted to it by the electron stream as a green display. The visible light output decays to 1 percent of its initial value in approximately 50 milli-seconds after electron excitation ceases. The continued emission of visible light after bombardment has ceased is known as phosphorescence. The screen of the scope tends to charge negatively when bombarded by electrons and would repel the approach of further electrons unless the scope screen is freed of negative charges. Also secondary emission takes place, which will create a space charge repelling and limiting further electron flow from the cathode. A collector, or aquadag, voltage of positive 1,500 volts is tied to a conducting coating of aquadag on the inside front of the tube near the screen, which collects the electrons caused by secondary emission. The aquadag prevents space charges and negative charges from building up on the screen, thus allowing the screen to continue to attract the electron beam.

Section IV. PPI

18. OVERALL FUNCTION

a. The PPI V609 is a 10KP7 cathode-ray tube that employs electromagnetic deflection and focusing, which offers several advantages. A greater angle of deflection can be obtained with electromagnetic tubes, reducing the tube length and chassis size for the same sweep length. High anode potentials can be used to increase the screen brightness without introducing the focusing difficulties of electrostatic tubes. Of utmost importance, the magnetic deflection coil can be mounted and rotated outside the tube for azimuth resolution without disturbing the proper sweep. The cutaway view of the PPI (fig 9) should be referred to in reading this section.

b. The electron gun (fig 9) is similar to that of the A-scope with electrons being emitted from an indirectly heated cathode surface. The emitted electrons are formed into a beam by passage through an aperture at the end of a cylinder, which serves as a control grid. The accelerating anode accelerates the stream of electrons from the control grid toward the screen of the scope. The electron beam is focused by an electromagnetic field developed by a focus coil located around the neck of the tube. This coil causes magnetic lines of force to form inside the tube. These magnetic lines of force act on the electrons and bend the electron paths much like the electrostatic field does, so that the focal point will be at the screen. The deflection of the electron beam by a deflection coil gives a radial line from the center of the screen, which is called electromagnetic deflection. The beam displays range data on the radial line and azimuth information by rotating the coil causing the radial line to turn. The deflection coil is moved in azimuth in synchronization with the rotation of the antenna. The range is measured with a linear time baseline in the same manner as for the A-scope; however, a trapezoidal voltage with a step or jump is necessary to overcome the inductance of the deflection coil. After the first step the voltage continues to rise linearly in amplitude. The resulting current waveform as well as the electromagnetic field increases at a linear rate the first instant the voltage is applied to the coil. The

electron beam, after being positioned by the electromagnetic field, strikes the screen and produces the PPI sweep. Intensity modulation may be introduced at any point on the sweep, depending on the relative range. A high positive potential is used as an aquadag voltage for removing negative charges from the screen.

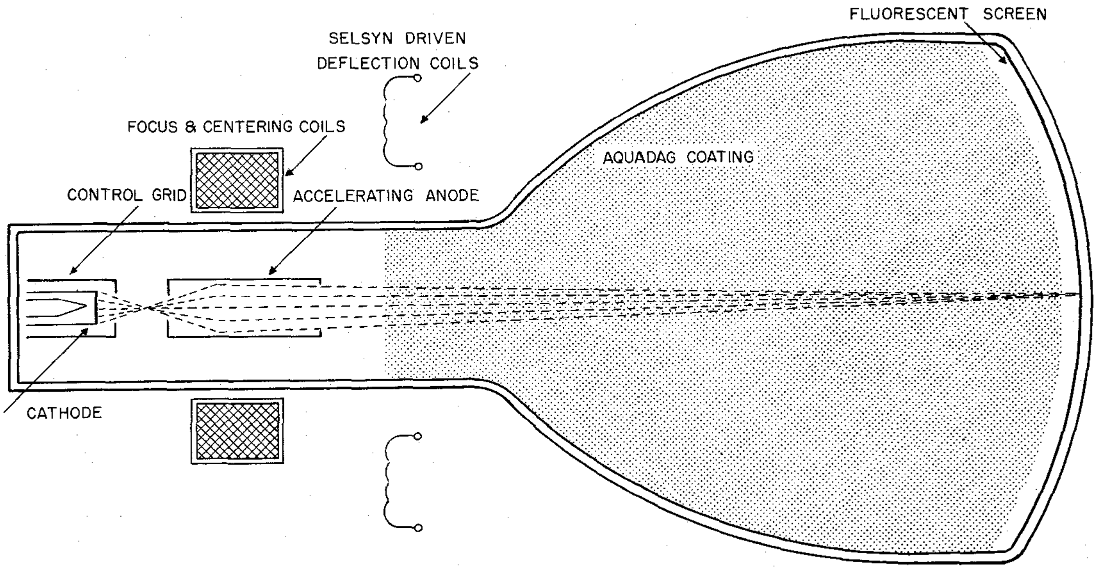

Figure 9. Cutaway view of the PPI.

19. CATHODE AND FILAMENT

a. The cathode, pin 11, is indirectly heated by the filaments, pins 1 and 12, and is kept at a positive dc potential by the COARSE INTENSITY control R660A/B and INTENSITY control R659. The potential, which with both controls set to their midpositions is approximately a positive 250 volts, also provides the dc level for the 6.3 volts ac applied to the filament. The dc filament voltage is made the same as the cathode's to prevent arcing between the two elements within the tube.

b. The radar and IFF video, the strobe marker, and the range marker signals are all applied to the cathode as negative potentials causing a greater quantity of electrons to be emitted from the cathode than in the absence of the signals. The negative signals increase the number of electrons in the beam; therefore, when the beam reaches the scope face a spot of greater intensity is observed on the sweep. The term intensity modulation refers to an increased intensity of the PPI, and the signals appear as intensified blips of light.

20. CONTROL GRID

The control grid, pin 2, controls the number of electrons in successive sweeps so that a baseline of uniform intensity will be obtained. It has applied an unblanking signal, which is a positive gate with a time duration equal to the desired sweep length. The positive gate

intensifies the trace during the time that information is to be presented. When the gate is returned to its zero reference level, the retrace of the sweep will be blanked by the reduced potential on the control grid.

21. FOCUS AND CENTERING COIL L602 (pins 1, 2, 3, 4, 5, and 6)

a. The electron beam is focused and centered by an electromagnetic field introduced by the FOCUS AND CENTERING coil L602, located around the neck of the PPI. The electrical potential of the coil causes magnetic lines of force that act upon the electron stream to form inside the tube. An electron path going directly through the center of the magnetic field passes along the axis of zero field strength, so its path is not changed by the action of the focusing field (fig 10). All electron paths not along this axis are bent back toward the path of zero field strength by the electromagnetic field so that all beams will converge at one spot on the screen (fig 10). The focal point is determined by the direct current flow through the focusing coil. If the electromagnetic field is too strong, the convergence point will be too short in relation to the scope face; the opposite condition is true for a weak field.

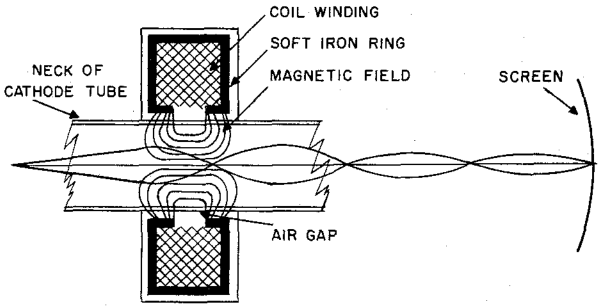

Figure 10. Electron beam focusing in the PPI tube.

b. The focusing is accomplished by the 1-2 winding of coil L602. The path of current flow through the coil windings is from ground through R671, R670, focus tube V610, R664, R663, and the focus coil to the 450-volt supply. A vacuum tube is used in the circuit so that a small potentiometer, R671, can vary the focus coil current adequately. Increasing the resistance of the FOCUS control R671 increases the positive cathode bias on V610. This increased bias on V610 reduces the current flow through the focus coil, thereby reducing the electromagnetic field. Thus, V610 acts as a grounded grid dc amplifier to augment the change in current introduced by a change in the value of R671.

c. The electron beam is centered by two centering coils, windings 3-4 and 5-6, which are physically part of the focusing coil assembly L602. The windings are placed so that their fields are at right angles. The field strength of the windings is determined by the direct current flow through them and is made variable by the PPI CENTERING resistors R662 and R665. The current through the 3-4 winding is varied by R662 and through 5-6 winding by R665. These potentiometers are used to position the electron beam spot at the center of the screen under no deflection condition, and an incorrect setting will cause the sweep end to vary about the edge of the scope face with changes in azimuth.

22. DEFLECTION COIL L601

a. The deflection coil L601, composed of two windings with an air core, is mounted in a ring that fits about the neck of the PPI tube. The coil is connected between the plate of the PPI power amplifier V608 and the power supply voltage of 450 volts. It provides the plate load for V608, the current being applied through the coil with a brush and slipring arrangement.

b. The deflection coil's opposition to the flow of current is made up of inductance and resistance. The resistance is distributive across the windings of the coil and not a lumped sum value, definitely not to include R657. The equivalent circuit is shown in figure 11. The current flow through the coil must cause the magnetic field to build up at a linear rate to a value sufficient to cause the electron beam to move to the outside of the PPI in a radial pattern. Since the magnetic field strength varies directly with the current in the coil, any linear deflection of the spot requires a linear variation of the current through the coil. Because a sawtooth current is necessary to give accurate ranging, the voltage waveshape must be trapezoidal with the initial instantaneous rise called the jump voltage (fig 11(2)). The jump in the voltage is required to start the current flow through the inductance of the coil. After the jump voltage, the slow increase is the slope voltage, which continually compensates for the drop across the distributive resistance of the coil. The resulting current (fig 11(3)) is necessary to increase the magnetic field within the tube so the electron beam is deflected for ranging.

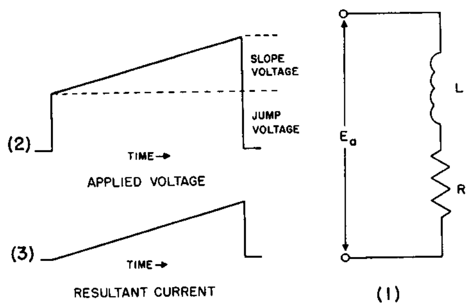

Figure 11. Deflection coil and waveforms.

c. For any sweep range, the ratio of the jump voltage to the slope voltage is the essential quantity for sawtooth current. Within the total sweep of 5 inches, there must be displayed sweep ranges of 20, 40, 80, and 160 nautical miles. For the same physical sweep length to represent four different ranges of display, the trapezoidal voltage waveform, as well as the current, must change. For a 20-mile sweep, the jump voltage must be much greater than for a 160-mile sweep because the current flow must be greater in respect to time (fig 12). Regardless of the sweep range, the same maximum current is required to deflect the electron beam to the outside of the scope face; therefore the current increases much faster for a 20-mile sweep than for a 160-mile sweep. The high jump voltage is necessary to overcome the inductive reactance of the coil, which is greater for the fast-current rise time at the 20-mile sweep than it would be for the slow-current rise time of the 160-mile sweep. The higher jump voltage enables the current to flow more rapidly for the shorter sweep. It must be realized for the 20-mile sweep that when the current has increased to

one-half its maximum amount, the electron beam must be deflected over one-half its sweep length even though it now displays 10 miles or 123.8 microseconds. However, under the same current condition for the 160-mile sweep, the electron beam is still deflected one-half its total sweep length, which is now 80 miles or 990.4 microseconds. Notice that the current must rise faster for this short sweep range, thus the necessity of a higher jump voltage to give the faster current rise. As the sweep range is decreased, the time rate of current rise must be greater than for a long sweep range. Thus, for the shorter sweep ranges the current must rise more rapidly in respect to time. The variations of the time rate of current do not affect the dc resistance of the coil, hence the slope voltage amplitude remains constant for all sweep ranges. The same slope voltage amplitude must be the resultant at the end of the different sweep ranges, because the effect of the distributive resistance on the increasing current must be overcome to maintain a linear rise of current.

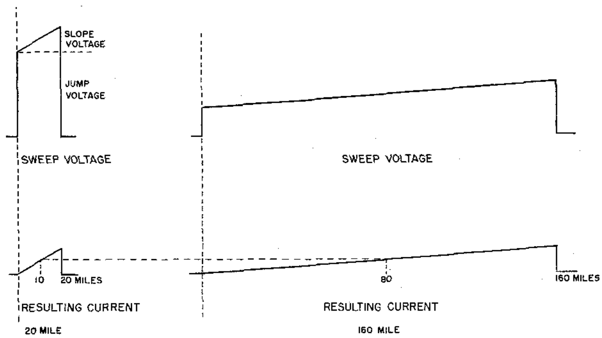

Figure 12. Voltage and current waveform required for 20- and 160-mile sweep lengths.

d. The sweep deflection from the center to the outside of the PPI screen can be seen in figure 13. The sawtooth current waveform is applied to the deflection coil at point A on the waveform, and the electron beam is at the center of the screen since no electromagnetic deflection is introduced. This is the condition of the electron beam before or at the time the transmitter fires. After the transmitter fires, the trapezoidal voltage creates a current flow, A to B, and the electron beam is slowly deflected to point B and on to points C, D, and E. At E the current flow stops and the electron beam retraces to the center of the screen until the next sweep current starts with the following transmission. The shunt resistor R657 provides a damping of the current when it drops back to its reference point to give an immediate retrace. The deflection recurrence rate of the electron beam and the persistency of the screen (7 seconds) enable the physical display of the beam to appear as a continuous radial line.

e. The deflection coil is mechanically rotated by a Selsyn motor B602, which causes the electromagnetic field to rotate within the tube. The rotation of the field causes the radial sweep to rotate in synchronization with the antenna to provide azimuth information.

23. SCREEN AND AQUADAG VOLTAGE

The fluorescent screen on the PPI is composed of two layers of screen material, the combination of which exhibits sustained phosphorescence of 7 seconds. The inner material

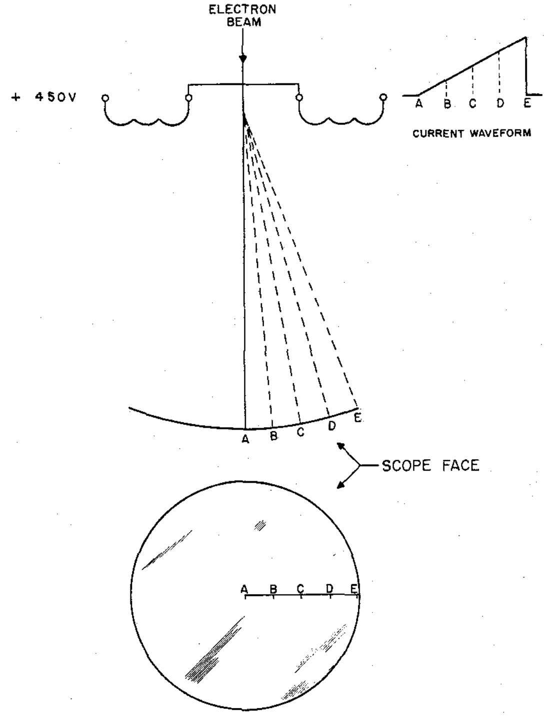

Figure 13. PPI sweep deflection.

when bombarded by the electron beam fluoresces with an extremely blue light. The blue light excites the second layer, which responds with a highly persistent, visible yellow light. The aquadag has a positive 8,000 volts applied to remove secondary emission electrons that are reflected off the screen. It also provides an electrical and optical shield which prevents undesired deflection or defocusing of the electron beam.

Section V. SUMMARY AND QUESTIONS

24. SUMMARY

a. A-scope. The A-scope presents a display of range only, at sweep ranges of 20, 40, 80, or 160 nautical miles on a 5-inch sweep length. A 10-mile EXPAND sweep of any sector of the PPI sweep from 10 to 160 miles can be viewed. The scope uses electrostatic deflection with a sawtooth voltage and current necessary for linear sweep and accurate ranging. The video and range markers are displayed as positive signals along the horizontal baseline. The A-scope sweep circuits generate the unblanking and sweep voltage for the proper operation of the scope.

b. PPI. The PPI uses electromagnetic deflection for sweep ranges of 20, 40, 80, or 160 nautical miles on a 5-inch sweep length. The sweep or time base is a radial line that begins

at zero range at the center of the screen and increases in range toward the outside. The radial sweep is rotated in synchronism with the antenna to give azimuth resolution to targets. In electromagnetic deflection a trapezoidal voltage is required to give a sawtooth of current through the deflection coil. The linearly rising current flow increases the electromagnetic field and moves the sweep outward on the PPI screen for ranging. The range markers, IFF video, radar video, and strobe marker signals increase the number of electrons striking the scope face and give intensity modulation.

c. Range markers and strobe. Range markers appear at 5-mile intervals on the A-scope and PPI with sweep ranges of either 20 or 40 miles, and with the EXPAND sweep on the A-scope. With 80- or 160-nautical mile sweep lengths, the range markers appear at 25-mile intervals. These markers afford more accurate range determination than is possible with a solid baseline. The strobe marker is variable in range from 10 to 160 nautical miles and is seen only on the PPI. The strobe initiates the EXPAND sweep for the A-scope; therefore, any 10-mile portion of the PPI sweep from 10 to 160 miles can be viewed on the A-scope screen.

25. QUESTIONS

a. What type of deflection is employed in the A-scope? PPI?

b. What are the voltage and current waveforms necessary for a linear sweep on the A-scope? PPI?

c. Why is a linear sweep necessary in ranging?

d. How is the EXPAND sweep originated and what is its full length?

e. What are the variable limits of the strobe marker?

f. When are the 5-mile range markers used? The 25-mile markers?

g. What is the effect on electron emission and presentation when the negative video, range markers, and strobe signals are applied to the PPI cathode?

h. What is the polarity of the signals and their effect on the top vertical deflection plate of the A-scope?

i. What is the purpose of the unblanking voltages for the scopes?

j. With a 20-mile sweep length representing 5 inches, how far from the left must the electron beam be deflected to represent 5 miles (physically)?

k. In order to represent accurately a target at 30 nautical miles, how many microseconds are necessary in sweep circuits to range the target?

l. Why is the jump voltage needed for electromagnetic (PPI) deflection? The slope voltage?

m. On the A-scope, if it takes 100 volts of maximum amplitude to give a 20-mile sweep length, how much voltage is required to give a 160-mile sweep length?

n. Draw to scale the sweep voltage waveform for the A-scope with sweep ranges of 20 and 160 nautical miles.

o. What data are obtained from the A-scope and the PPI?

p. How is focusing accomplished on the PPI?

q. By increasing the resistance of the FOCUS control R671, will the focal point increase or decrease in distance from the cathode?

r. What is the voltage on the cathode when the COARSE INTENSITY control R660A/B is set to midposition and the INTENSITY control R659 is set for minimum resistance (upward position)?

s. Why is aquadag voltage needed for the scopes?

t. What is the purpose of C659? If misalined, what is the effect on presentation?

CHAPTER 3

A-SCOPE AND PPI SWEEP AND STROBE MARKER CIRCUITS

Section I. A-SCOPE SWEEP CHANNEL

26. GENERAL

a. The A-scope displays slant range information of target returns that enter the radar antenna. In order to display range accurately, sweep circuits that will produce a horizontal baseline with correct graduations of range at any particular point on the sweep are necessary. Range baseline presentations are possible for a 20-, 40-, 80-, or 160-nautical mile display when initiating the sweep circuits by the synchronizing trigger from the transmitter. A 10-mile display of expanded range, variable between the limits of 10 to 160 nautical miles, is available when triggering the sweep circuits by the strobe marker.

b. The PPI presents slant range and azimuth data of detected targets. The slant range baseline originates at the center of the screen and sweeps radially outward to increase range. The sweeping of the radial line from center to the outside of the screen is accomplished by the sweep circuits that provide the deflecting voltages. The movement of the sweep in azimuth is synchronized by the antenna servosystem.

c. The strobe marker gives greater accuracy in ranging by the expansion on the A-scope display. It is variable in range from 10 to 160 nautical miles and appears as an intensity-modulated spot on the PPI sweep baseline. The A-scope can be triggered from any particular position of the strobe and will display a 10-mile sweep length that begins at the range of the strobe marker. As the strobe position is changed, therefore, the beginning of the EXPAND sweep on the A-scope is varied in time, and the range about a target is expanded in its scale of presentation.

27. A-SCOPE RANGE SELECTOR SWITCH S609

a. The S-scope RANGE SELECTOR switch S609 is a 6-wafer switch with A, B, C, D, E, and F sections. The purpose of the complete switch is to change the appropriate circuit constants in the sweep channel to produce the correct sweeps for the 10, 20, 40, 80, and 160 nautical miles of display.

b. The wafer section of S609A selects the input trigger for the A-scope gate multivibrator V622. The 20-, 40-, 80-, and 160-mile positions are connected, and in these settings, the trigger comes directly from the pulse transformer T502 in the transmitter unit. When S609A is in the EXPAND position, the multivibrator is triggered by the positive-going trailing edge of the differentiated square wave output from the strobe delay multivibrator V621.

c. S609B section selects the proper plate load for V622B to give the desired amplitude of the positive-going square wave for the proper unblanking voltage to the scope. S609C applies the correct capacitance to the grid circuit of V622B to set the time constants of the multivibrator for the various gate lengths. S609D selects the capacitance for the plate circuit of the sweep generator V623, which determines the rate of slope rise in the output

voltage and the deflection speed of the horizontal sweep across the scope face. S609E and S609F provide the switching arrangement for the selection of the 5- or 25-mile range markers for the A-scope.

28. A-SCOPE SWEEP MULTIVIBRATOR V622

a. The positive trigger from the pulse transformer (fig 15(1)) is approximately 100 volts in amplitude, 2 microseconds in duration, and occurs for each transmission. The secondary winding in the pulse transformer takes off the trigger pulse at the same time the magnetron is pulsed, and the pulse is cabled to the indicator where it is applied across a voltage divider consisting of R680 and R681. The output to trigger the sweep channel, which is taken across R681, is one-eighth the amplitude of the original signal or approximately 13 volts. This reduced trigger is coupled to the PPI sweep multivibrator V603, the range mark gate multivibrator V614, and the strobe delay multivibrator V621. It is also used to trigger the A-sweep multivibrator V622 when S609A is set in the 20-, 40-, 80-, or 160-mile positions.

b. The A-scope sweep multivibrator is triggered by the positive trigger from either the pulse transformer or the strobe multivibrator depending upon the position of S609A. The outputs are two square waves, 180° out of phase, with the leading edges of both square waves always occurring at the time that the multivibrator is triggered (figs 15(2) and 15(3)). The time for the trailing edges of both waves can be changed by S609C, which changes the time constant of the multivibrator circuits to the correct time value for the selected sweep range. The leading edges of the waves start the sweep on the screen and the trailing edges terminate the sweep. The length of the wave from the leading to the trailing edge is known as the gate length. These voltage waves start and stop, or gate, the length of time that the sweep circuits will operate. The positive square wave (fig 15(3)) is applied to the control grid of the range scope and gates the length of time the scope will conduct. The negative square wave (fig 15(2)) is applied to the sweep generator V623 and gates the length of time that the sweep generator will generate a sawtooth. Since the gate lengths of the positive and negative square waves are identical, the scope only conducts during the time of the sweep, being blanked out during the retrace time until the recurrence of another sweep. On the 20-, 40-, 80-, or 160-mile positions of S609, the sweep gate starts with the firing of the transmitter. On the EXPAND position of S609A, the start of the sweep gate is delayed for a number of miles determined by the position of the range strobe control, which designates the amount of delay in the strobe delay multivibrator V621. In this position of S609A, the trigger from the pulse transformer is disconnected and the delayed trigger is connected to the A-scope gate multivibrator.

c. The A-scope sweep multivibrator V622 is a one-shot multivibrator with the grids of both sections connected by voltage dividers to B+. The operation in the quiescent state is discussed in this paragraph. R1664 and R1667, constituting a voltage divider network tied to a positive 300 volts, apply a fixed positive 51 volts to the grid, pin 2, of the A-section. The B-section grid bias is obtained by the voltage divider network R1671 through R1675 and by the dc restorer V604B. The resistor network places a +75 volts on the cathode of V604B, which conducts, putting the B-section grid, pin 7, at a positive 75-volt potential, insuring that the static charge on the sweep condensers C648 through C652 is returned to the same value at the time of each input trigger pulse. The positive 75 volts on the grid

causes the B-section to conduct, and about 75 volts is dropped across cathode resistors R1665 and R1666. The positive 75 volts on both cathodes puts a negative 24 volts (51 volts minus 75 volts) of bias on the A-section, which is sufficient to cut it off. C649, C650, C651, and C652 are the coupling condensers between the plate of the A-section and the grid of the B-section. The position of S609C determines the number of capacitors that are connected in parallel. Since the A-section is cut off, the positive 300-volt B+ will be applied to one side of the condensers. The other sides of the condensers are tied to the 75 volts, which is applied to the grid of the B-section, and a difference potential of 225 volts (300 volts minus 75 volts) is charged across the coupling condensers.

d. The positive trigger, coupled to the grid of the A-section, raises the grid voltage of the section from a negative 24-volt bias level to above cutoff, causing the A-section to conduct. Current flow through the A-section drops about 100 volts across the plate-load resistor R1668, causing the plate voltage to drop about 200 volts. Therefore, the applied voltage difference between the A-section plate and the B-section grid decreases about 100 volts, and the capacitors C648 through C652 immediately start discharging through R1670 and R1669. This discharge through R1669 and R1670 gives a 100-volt drop across the resistors. This places the B-section grid at a negative 25-volt potential, which cuts it off. The current flow through the A-section drops about 50 volts across the cathode resistors. After the trigger duration, the A-section grid is returned to a 51-volt fixed bias, which permits the A-section to continue to conduct with zero volts bias. With the A-section now conducting and the B-section cut off, the plate voltage on the A-section has dropped from 300 to 200 volts to start the negative gate, and the plate voltage of the B-section has increased to 300 volts to start the positive gate. These gates start simultaneously with the triggering of the multivibrator.

e. With the cathodes at a positive 50 volts and the grid of the B-section at a minus 25 volts, a bias of 75 volts is felt initially on the B-section. The cutoff bias for the section is about 18 volts; therefore, it is biased initially upon the signal input at 57 volts below cutoff. The coupling condensers, however, immediately start discharging through R1669, R1670, and the power supply. The net discharging voltage is 325 volts, so the coupling condensers must discharge 18 percent of their voltage before the condensers have discharged to the cutoff value of the B-section. It takes two-tenths of a time constant for a condenser to discharge 18 percent of its applied potential. With the range selector switch S609 in the 20-mile position and the A-GATE control R1669 in its midposition, the time constant of the multivibrator is determined by R1670, C649, and half the resistance of R1669. Thus the time constant of the multivibrator is 1,264 microseconds, and the two-tenths of this time constant is 252.8 microseconds, which is slightly more time than is necessary for a 20-mile sweep. The 247.6 microseconds necessary for a 20-mile sweep can be set exactly by adjusting the A-GATE control R1669 in the discharge path. For each increase in range, the capacitance is doubled. For instance, one time constant for the 40-mile sweep is increased to approximately 2,528 microseconds. Two-tenths of this constant is about 505 microseconds. Therefore, by adjusting R1669 to the correct sweep value under any one sweep range condition, the sweep gates can be changed by the switching arrangement of the condenser circuit.

f. When the coupling condensers have discharged to the cutoff value for the B-section, it starts to conduct, which immediately raises the cathode voltage on both cathodes, increasing

the bias, cutting down the conduction, and raising the A-section plate voltage. This increase in plate voltage is coupled through the coupling condensers to the B-section grid, raising the voltage on the grid to 75 volts to permit conduction of the B-section, which causes the common cathode voltage to rise to 75 volts cutting off the A-section. The increase in voltage felt on the grid of the B-section is also felt on the plate of the clamper tube V604B. When the plate voltage on the clamper reaches 75 volts, it conducts and quickly charges the coupling condensers through R1675 and the clamper tube. Some grid current from the B-section will also aid in charging the capacitors. The operation of the multivibrator has now returned to its original quiescent state and will remain so until another trigger is applied. With the A-section now cut off and the B-section conducting, the A-section plate voltage again rises to 300 volts to end the negative gate, while the plate voltage of the B-section again drops to end the positive gate. The length of these gates is determined by the time constant of the multivibrator, which is determined by the capacitance of the coupling condensers and the value of R1669 and R1670. Monitoring at TP609, the action of the multivibrator is shown by its positive square wave output. The value of the capacitance is changed to vary the range; the value of R1669 is variable as a fine adjustment to compensate for tolerances in the values of circuit components. V604B returns the grid of the B-section to 75 volts at the end of each gate. The divider network R1671 through R1675 keeps 75 volts on the cathode of V604B at all times. If the plate of V604B attempts to go above 75 volts, the diode will act as a short and keep the plate of the diode at the cathode voltage of 75 volts. The plate can be at any amount below 75 volts, in which case V604B will act as an open circuit. Thus V604B clamps the B-section grid potential at or below 75 volts.

g. The resistance of the plate load of V622B is varied by S609B for changes in sweep ranges. In the EXPAND and 20- and 40-mile positions, R1661 is placed in parallel with R1662 and R1663. The plate resistance is increased in the 80-mile position by switching a larger resistance, R1660, into the circuit instead of R1661; for the 160-mile sweep, the plate load consists of only R1662 and R1663. As noted from the above, the resistance is increased for the longer sweeps. The output taken across the plate resistors of V622B is the unblanking gate, which is used to give the proper intensity of the electron beam in its sweep from left to right on the screen of the A-scope. This control of intensity is accomplished by a change of voltage in a positive direction being applied to the control grid of the range scope during the sweep time and, at the end of this positive voltage gate, the control grid being returned negatively to give blanking of the electron beam during the retrace. It

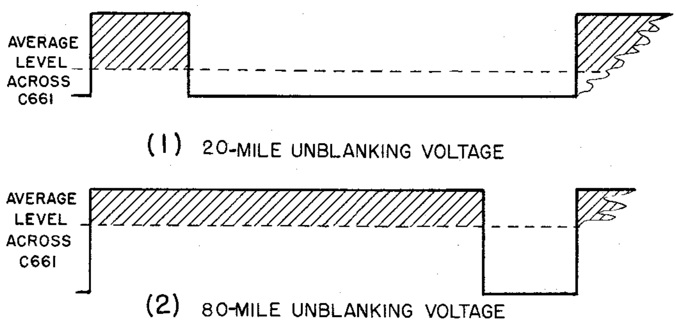

Figure 14. Unblanking voltage waveforms and average voltage level.

must be remembered that the difference in potential between the control grid and cathode determines the number of electrons emitted by the cathode. Since the cathode is set at a constant potential, the emission is changed by control grid voltage changes. During the faster sweeps (short sweep ranges), the amplitude of the unblanking pulse must provide a heavier conduction of the cathode-ray tube; therefore, its positive amplitude must be greater at the control grid than for a slower sweep (long sweep ranges). Because of the resistance arrangement in the plate of V622B, the unblanking gate is smaller in amplitude for the short ranges, which is just opposite of the needed signal at the control grid. Since the unblanking voltage is applied to the control grid, pin 3, of the cathode-ray tube by C661, the dc voltage variation on the plate of V622B is changed into an ac variation at the control grid. These ac variations ride at a negative 1,500-volt level that appears at the grid through R1691. The positive output of V622B is smaller in the EXP and 20- and 40-mile positions than for the 80- and 160-mile sweep lengths; however, in the EXP and 20- and 40-mile positions the gate pulse is much narrower and the average potential level appearing at the control grid is lower, as seen in figure 14(1) for the 20-mile position. Therefore, for the shorter sweeps, a lower average level is obtained across C661 and a larger voltage gate is reflected on the control grid causing the conduction of the A-scope to be increased for the proper brilliance of the baseline. When the range is increased to 80 miles, the unblanking gate is much longer, thus the average level potential on C661 is increased (fig 14(2)). Due to the increased average level during the long sweep ranges, the gate from V622B must be increased to give a larger gate above the average level. The action of the entire circuit of the plate-load resistors and C661 is to provide uniform intensity to the A-scope display for all sweep ranges.

h. C648 at S609C is shorted for all positions except EXPAND where the short is removed when C648 is placed in series with the parallel combination of C649 through C652. This series-parallel condenser circuit gives one-half the total value of capacitance that was used on the 20-mile sweep. When V622A is triggered by the trailing edge of the strobe multivibrator V621, it is allowed to conduct for approximately 123 microseconds to provide a 10-mile sweep gate and unblanking pulse. After being triggered by the strobe multivibrator, V622 operates exactly in the manner explained in a to g above.

29. SWEEP GENERATOR V623

a. The A-scope sweep generator V623 produces a sawtooth voltage (fig 15(4)), which begins with the start of the negative gate from V622A and increases in a positive direction until the end of the gate at which time it immediately drops to its original value. This voltage is applied to a paraphase amplifier that produces the deflection voltages. With no signal applied, the grid and cathode are both grounded and the tube is conducting with zero volts bias. The high value of the plate-load resistors R1676 and R1677 causes the plate to be only a few volts above the cathode potential or ground. The capacitors at S609D are tied between the plate and ground of V623. The negative gate from the multivibrator is coupled to the grid of V623 by C653 and R1678 and cuts off V623 for the duration of the gate. With V623 cut off, it acts as an open circuit and current flows through the condensers connected in parallel with V623 and in series with R1676 and R1677. These condensers charge exponentially through R1676 and R1677. At the end of the gate length, the grid of V623 is again returned to ground potential and V623 conducts, shorting out the capacitors and quickly returning them to their original charge of only a low voltage.

b. The value of the sawtooth voltage (fig 15(4)) is determined by the gate length and the time constant of the capacitance and resistance in the circuit. For the 20-mile range with R1676 in the midposition, the time constant is dependent upon C657, R1676, and R1677 and is equal to 9,100 microseconds. Since the capacitor is allowed to charge for only the gate length of approximately 248 microseconds, it charges to about 3 percent of one time constant. This first 3 percent is an extremely linear part of the curve and so provides a linear sweep voltage. For each increase in range, another capacitor is added by S609D between the plate of V623 and ground to double the capacitance of the circuit. This added capacitor doubles the time constant of the sweep generator circuit and causes the capacitors to charge only half as fast. At the same time, S609C doubles the gate length and causes the capacitors to charge twice as long. With the capacitors charging half as fast and twice as long, they charge to the same potential value as before in twice the time, which provides for a sweep to be the same physical length as before but sweeping twice as long to represent twice the electrical length or range. For every further doubling of the range, S609D again doubles the capacitance in the sweep generator to keep the total charge on the capacitors and the physical length of the sweep constant while S609C doubles the gate length, thus doubling the electrical length or range. A fine adjustment is provided by the SLOPE control R1676, which is in the charge path of the sweep capacitors to vary the rate of charge or the slope of the sawtooth. It is adjusted so that the final amplitude of the sawtooth applied to the deflection plates is sufficient for a full sweep across the screen.

c. On the EXPAND position of S609 it is desired to reduce the range of the sweep to 10 miles. Thus instead of doubling the time constant, it is necessary to reduce it to one-half

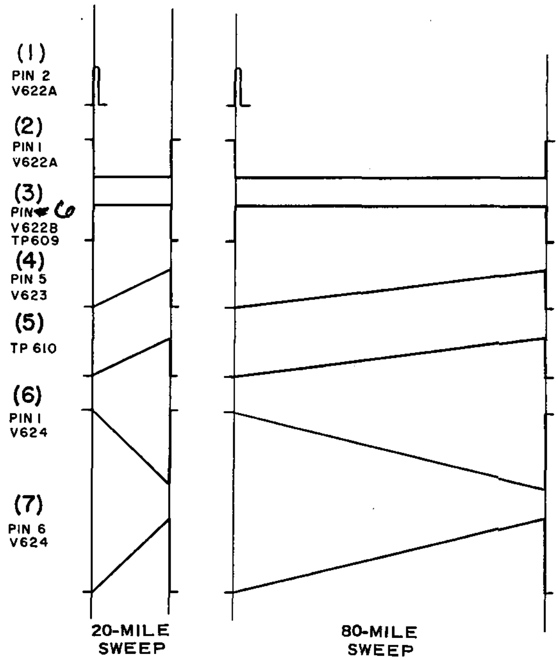

Figure 15. Voltage waveforms in the A-scope sweep channel.

the 20-mile position. This reduction is done with C658, which operates much like S648 of S609C and is shorted out for all positions of S609D except EXPAND. In this position the short is removed and C658 is placed in series with the parallel combination of the four capacitors used on the 160-mile position. This series-parallel arrangement reduces the time constant of the sweep generator to one-half the 20-mile position time constant. At the same time, the addition of C648 in the sweep multivibrator reduces the gate length to 10 miles. Thus the capacitors charge to the same potential as before during a 10-mile gate and provide the same amplitude of sweep voltage as for the other sweeps. The rise time of the sawtooth is at a faster rate producing the 10-mile sweep length.

30. SWEEP INVERTER AMPLIFIER V624

a. The A-scope sweep inverter amplifier V624 is used to produce two amplified sawtooth voltages (fig 15(6) and (7)) that are 180° out of phase. Its outputs are applied to the horizontal deflection plates of the A-scope to provide for the horizontal push-pull deflection of the electron beam. The cathodes are tied to a negative 150-volt supply through the common cathode resistors R1685 and R1686. An additional cathode resistor R1684 appears in the cathode circuit of the B-section. R1682 and R1683 are the plate-load resistors of the A and B sections respectively. The plate of the A-section is tied directly to the left deflection plate and the plate of the B-section directly to the right deflection plate of the A-scope. Both sections are normally conducting. The grid of the A-section is directly coupled to the plate of the sweep generator V623. With no signal applied, this makes the A-section grid only a few volts above ground. The grid of the B-section is tied to the center of a voltage divider consisting of the HORIZONTAL CENTERING control R1687 and a fixed resistor R1688. With R1687 in its midposition, the B-section grid potential is approximately +11 volts. Therefore, with no signal applied, the grid of the B-section is more positive than the grid of the A-section. This condition causes the B-section to conduct more than the A-section, giving a greater voltage drop across the B-section plate load than across the A-section plate load, which will put the B-section plate and the right horizontal deflection plate at a lower potential than the A-section plate and the left horizontal deflection plate of the A-scope. Thus, the negative potential on the right deflection plate will push the electron beam away from it; the positive left deflection plate will pull the electron beam toward it. This combined pushing and pulling action places the electron beam on the left side of the screen under a no-signal condition. The exact position of the spot on the screen is determined by the position of the HORIZONTAL CENTERING control R1687, which determines the conduction state of the B-section.

b. The positive-going sawtooth (fig 15(4)) applied to the grid of the A-section drives the grid increasingly positive, causing the A-section to conduct at a steadily increasing rate, which causes the plate voltage of the A-section and the left deflection plate to go steadily negative (fig 15(6)), increasing the pushing effect exerted by the deflection plate on the electron beam and causing it to move to the right. At the same time, the increased conduction of the A-section causes a positive sawtooth of voltage to form across the common cathode resistors. This positive-going sawtooth is applied to the cathode of the B-section causing it to conduct at a steadily decreasing rate. This causes the voltage on the B-section plate and the right deflection plate to go more positive (fig 15(7)) increasing the pulling effect exerted by the deflection plate on the electron beam. In this manner, the electron beam moves to the right. The push-pull action, or deflection, is continuous for the duration of the applied sawtooth causing the electron beam to move from the left to the right.

At a time that is halfway through the sweep, both sections of the sweep amplifier are conducting equally. Their plate voltage and the voltage on the deflection plates are the same and cause the electron beam to be in the center of the screen. From this point, the A-section conducts more than the B-section, which makes the left deflection plate even more negative. The sawtooth of voltage on the cathode continues to build up causing the B-section plate and the right deflection plate to continue to go steadily more positive. By having a linear change in the push-pull of voltage that is applied, the electron beam is deflected at a constant rate across the face of the scope. At the end of the sawtooth applied from the sweep generator, the voltage on the grid of the A-section goes back to its original value. This causes both cathode and plate voltages to revert back to their initial values, returning the electron beam to the left side of the screen. There the beam remains until another trigger initiates a new sweep cycle from the sweep multivibrator. The return of the electron beam to the left is blanked, so the retrace cannot be seen. The screen is kept from conducting by the unblanking pulse being returned to its original value. Because the retrace occurs very quickly, the number of electrons is insufficient to be visible due to the reduced voltage on the A-scope control grid.

Section II. PPI SWEEP CHANNEL

31. PPI RANGE SELECTOR SWITCH S606

a. S606. The range for the PPI is selected by the positioning of the PPI RANGE SELECTOR S606, which provides the changing of appropriate circuit constants in the sweep channel. The switch is composed of 5-ganged sections, A, B, C, D, and E, with each section having four positions for 20-, 40-, 80-, and 160-nautical mile sweeps.

b. S606A. The A-section of S606 switches the proper capacitance into the grid circuit of V603B, thus setting the time constant of the multivibrator to insure proper gate lengths for the PPI sweep generator V605 and the unblanking pulse. As the switch is positioned from the 20-mile to the 40-mile position, C611 is added in parallel with C610. Since the condensers have identical values, the total capacitance for the 40-mile sweep is twice that of the 20-mile. Also, the capacitance is doubled over the smaller range setting when switching to the 80- and 160-mile positions.

c. S606B. The position of S606B selects the capacitance in the plate circuit of the sweep generator V605. The amount of capacitance determines the degree of slope for the sweep voltage that provides the speed of the electron beam deflection across the scope face. As with S606A, the capacitance is doubled when switching from one sweep range to the next consecutive longer range.

d. S606C. S606C sets the proper size of resistor into a voltage divider network in the output of V603B. In the 20-mile position, R654 is placed in series with R656 and R655, giving a greater resistance in the bottom leg of the divider network and providing a greater amplitude to the positive unblanking pulse. As the range selection is increased, a smaller resistance is set into the divider by S606C, decreasing the amplitude of the unblanking pulse.

e. S606D and S606E. S606D connects the 5-mile range markers into the cathode of V602 when it is positioned for the 20- or 40-mile sweep. When switched to the 80- or 160-mile

range, it connects the 25-mile range markers to the cathode of V602. S606E shorts the 25-mile markers to ground in its 20- and 40-mile positions and shorts the 5-mile markers to ground in the 80- and 160-mile sweep ranges. With S608B set to the TEST position, S606E will not short the 5-mile markers to ground; therefore, they appear on the PPI along with the 25-mile marks.

32. SWEEP MULTIVIBRATOR V603

a. The PPI sweep multivibrator V603 is triggered by the trigger pulse that originated in the pulse transformer and is attenuated by R680 and R681 to a 13-volt amplitude (fig 16(1)). Since the stage is identical in operation to the A-scope sweep multivibrator V622, a detailed discussion of multivibrator operation will not be covered again. For detailed operation, refer to paragraph 28. The outputs of V603 are two square waves, having a 180° phase relationship, with a positive gate from the B-section and a negative gate from the A-section. The positive output from V603B (fig 16(3)) is used to unblank the PPI for the duration of the sweep; the negative output from the A-section (fig 16(2)) is employed to gate the sweep generator circuits. The leading and trailing edges of both outputs begin and end at the same time. The trailing edges are variable in time in order to vary the sweep ranges on the screen. An increased gate length is obtained by increasing the capacitance in the plate of the A-section. As S606A is switched from the 20- to 40-mile position, C611 is placed in parallel with C610, thus doubling the time constant of the multivibrator. This doubling of the time constant always occurs when switching to the next longer sweep range. The PPI GATE control R626, which is in the discharge circuit of the A-section plate condensers, gives a fine adjustment of the gate electrical length. The operation of V604A is the same as V604B in the A-sweep channel.

b. The unblanking voltage is a negative 248-, 495-, 990-, or 1,981-microsecond square wave with the width determined by the 20-, 40-, 80-, or 160-mile sweep. It is directly coupled to the voltage divider network R656 and R655 and the resistor in the S606C circuit. The amplitude of the plate signal is approximately 75 volts. When S606C is in the 20-mile position, the effect of the voltage divider R654 and R655 will be a 45-volt amplitude of the square wave at the grid of the PPI. For a longer range display, a slower electron beam deflection across the screen is the result, and the conduction of the PPI can be decreased. With a decreased conduction, the same brillance of the radial baseline is obtained. To decrease the scope conduction, a decrease in amplitude of the unblanking voltage is obtained by placing a smaller resistance into the divider network by S606C. For the 160-mile sweep, the amplitude of the positive gate at the control grid of the PPI is 44 volts, so the degree of conduction is just slightly changed in respect to the 20-mile sweep.

c. The negative output of V603A is coupled to the PPI sweep generator V605 to cut it off and cause the generation of the sweep voltage. Its time duration is identical to the unblanking voltage and represents the number of microseconds required to represent the 20-, 40-, 80-, or 160-nautical mile presentation.

33. SWEEP GENERATOR V605

a. The PPI sweep generator V605 produces a sawtooth voltage that begins with the start of the negative input gate and increases in a positive direction until the end of the gate

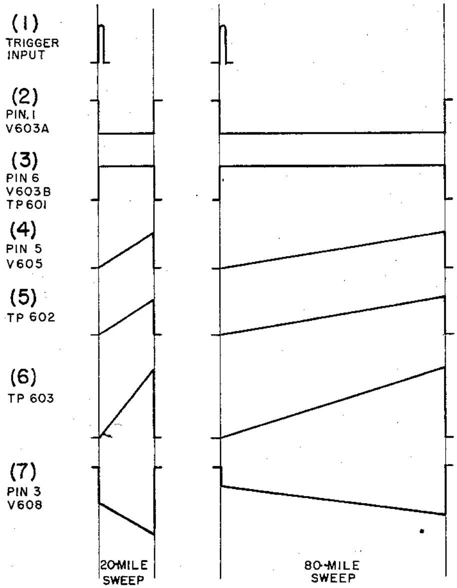

Figure 16. Voltage waveforms in the PPI sweep channel.

(fig 16(4)). The output positive-going sawtooth is coupled through three stages of amplifiers that shape and amplify the signal to drive the deflection coil. With no input signal, the grid and cathode are at a ground potential and the tube is conducting with zero bias. The high value of the plate-load resistor R634 causes the plate to be at a low potential. The capacitors C615 through C618 are tied between the plate and ground and are charged to the same potential as the plate voltage. During the conduction of V605, the capacitors have only a slight charge.

b. The negative gate from the gate multivibrator is coupled to the grid of V605 by C614 and R633 and cuts off V605 for the duration of the gate. When V605 is cut off, it acts as an open circuit and current flows through the switch-selected capacitors in the plate circuit. The condensers that are in the plate circuit, determined by S606B, will charge exponentially during the time that the tube is held cut off by the negative gate. The exponential charge places a positive-going voltage on the grid of V606A. The value of the sawtooth voltage is determined by the width of the input negative gate and the time constant of the capacitance and R634. For a 20-mile sweep range, the capacitance includes only C618, and the charge time constant is a function of C618 and R634. One time constant is then equal to 2,200 microseconds, but C618 is permitted to charge for only about 248 microseconds or 11 percent of a full charge. This first 11 percent provides a linear rise in the sawtooth voltage output. The amplitude of the voltage is dependent upon the width of the negative square wave input, which is determined by the PPI GATE control R626. As R626 is set to a specific value and not varied in changing sweep ranges, the output voltage amplitude of V605 will not change for different sweep ranges. However, the degree of slope will change from one sweep range to another. In the 40-mile

sweep, the time constant circuit is composed of C617, C618, and R634, which yields 4,400 microseconds for one time constant. The negative gate for the 40-mile sweep has a duration of 495 microseconds, so again the two capacitors will charge 11 percent of the applied voltage. The applied voltage B+ remains the same for all sweeps; therefore, the end result of voltage amplitude will remain the same. The additional capacitance at the longer ranges causes the condensers to charge slower and gives a slower slope rise.

34. SWEEP AMPLIFIERS V606 AND V608

a. The PPI sweep amplifiers V606 and V608 provide three stages of amplification for the sweep voltage that was generated by the sweep generator V605. The actions of both stages are discussed together since the cathodes of V606A and V608 have a common cathode resistance to give the necessary feedback that is used to generate the required jump voltage. V606A and V606B are two stages of voltage amplifiers and V608 is a power amplifier. Cathode self-bias is used on V606 and both sections are normally conducting. A voltage divider network of R644 through R647 applies a fixed negative 64 volts on the grid of the power amplifier V608 and the plate of the diode V607A. If the cathode of V607A attempts to go below a negative 64 volts, the diode conducts and acts as a short to keep the cathode at a negative 64 volts. As the cathode goes above 64 volts (more positive), the diode acts as an open circuit. From the clamper operation, the grid voltages on V608 is clamped at 64 volts but is allowed to go positive as the input signal is applied. This clamping of the bias insures an identical starting potential for each sweep.

b. The positive sawtooth voltage from V605 is directly coupled to the grid of V606A, which amplifies and inverts the sawtooth. The output negative sawtooth is taken off the plate of V606A and is RC-coupled to the grid of V606B, which again amplifies and inverts the sawtooth. This highly amplified positive sawtooth is coupled through C620 and R647 to the grid of V608. The power amplifier is initially biased about 8 volts below cutoff and does not conduct until the applied sawtooth decreases the bias for conduction. Before V608 begins conduction, the feedback is not effective and the overall gain of V606A is at its maximum value. When V608 begins conduction, it draws current through the cathode resistors R648 through R651 in addition to the current drawn by V606A through the same resistors. The increased cathode voltage drop is felt on the cathode of V606A as a degenerative feedback that reduces the gain of V606A. The initial high gain from V606A practically causes an instantaneous vertical rise in the voltage at the grid of V608, but once V608 starts to conduct the degenerative feedback (fig 16(5)) reduces the gain of V606A. The jump voltage is obtained from the high gain of V606A bringing V608 out of cutoff, but the resulting slope on the jump voltage is due to the sawtooth input to V608 (fig 16(6)).

c. The jump voltage on the grid, pin 5, of V608 is necessary to drive V608 out of cutoff. In its static condition V608 is biased to cutoff. The tube must be driven positively at a rapid rate to overcome the cutoff bias instantaneously. This action allows a high stability for each sweep when V608 goes into conduction. The inductance of the deflection coil resists the start of current flow through V608; therefore, the current flow starts slowly through V608, delaying the time that the degenerative feedback takes effect on V606A. As the initial resistance to current flow by L601 is overcome, V608 conducts more, which gives a greater voltage drop across the common cathode resistors and is felt as a degenerative feedback on V606A. This reduces the gain of the voltage amplifier and causes the positive-going

sawtooth on the grid of V608 to rise slowly for the remainder of the sweep. The net result is a negative trapezoidal voltage across the deflection coil (fig 16(7)), obtained by the sawtooth of current. The sawtooth of current through the coil gives a linear sweep for ranging. Test points TP602 and TP603 are available for monitoring the voltage waveforms with a synchroscope. The waveshapes are illustrated in figures 16(5) and (6).

d. The degenerative feedback also improves the linearity of the final output by compensating for an increase or decrease in the conduction of the two stages. If the rise rate of the input sawtooth voltage from V605 should decrease, the result would be a decrease in the sawtooth that is applied to V608. A similar decrease would be reflected into the feedback circuit, which would increase the gain of V606A to compensate for the decreasing rise. The SWEEP LENGTH control R651 varies the amount of voltage developed in the cathode of V608, which varies the degenerative feedback. It is adjusted to set the physical sweep length on the PPI.

e. The negative trapezoidal voltage (fig 16(7)) is applied to the deflection coil through the slipring assembly. The coil is rotated in azimuth by a synchro motor B601, which is connected to the antenna rotation circuits.

Section III. RANGE STROBE CHANNEL

35. STROBE DELAY MULTIVIBRATOR V621

a. The strobe delay multivibrator V621 produces the delayed trigger that is used to trigger the range gate multivibrator V622 when it is operating in the EXPAND position of the A-RANGE SELECTOR S609. The trigger occurs after a variable time delay of 10 to 160 nautical miles in respect to the time of the input pulse from the transmitter. The amount of delay is determined by the time constant circuits of the strobe multivibrator. S609 when set to EXPAND also changes the A-sweep channel components to shorten the sweep length to 10 nautical miles. The delayed trigger triggers the strobe blocking oscillator V613, which generates a marker that appears on the PPI. The position of the marker on the PPI indicates the number of miles of delay for any position of the RANGE STROBE control. It appears on the PPI screen as an intensity modulated spot and can be used to mark a particular range for special observation. The expanded sweep displays any 10 miles of range beyond the first 10 miles in detail and permits better target range resolution.

b. The strobe delay multivibrator V621 is a start-stop multivibrator with its time constant determined primarily by the coupling condenser C645 and R1657. The RANGE STROBE control R1657 is made variable to provide the means for varying the time constant of the multivibrator so that the square wave can be varied from 10 to 160 nautical miles. The fixed resistor R1658 provides a dc voltage for the proper quiescent voltage of V621. The multivibrator is triggered by the positive pulse from the pulse transformer (fig 17(1)), which determines the leading edge of the square wave. The variable trailing edge produces the delay strobe trigger and is determined in time by the operation of the multivibrator circuits.

c. A divider network applies a fixed 35 volts to the grid of the A-section and the grid of the B-section is tied to a potential of +150 volts. Grid current through R1657 keeps the grid of the B-section below the 150-volt level, but the potential is sufficient to cause the

B-section to conduct, raising the voltage across the common cathode resistors R1654 and R1656 above +35 volts, which cuts off the A-section. The positive pulse from the transmitter puts the A-section into conduction and its plate voltage decreases. The decreased voltage is coupled through C645 to the grid of the B-section, which cuts it off. The B-section remains at cutoff until C645 has discharged through R1657, R1659, and R1652, to a voltage that is sufficiently positive to raise the grid voltage above the cutoff value. When the B-section conducts, the multivibrator is returned to its quiescent state with the A-section cut off. The time at which the B-section goes back into conduction to end the square wave is determined by the cutoff potential of the B-section and the discharge time constant of C645. The value of the plate-load resistance is controlled by the TRIGGER ADJUST control R1655. As the resistance of R1655 is increased, the amount of plate voltage swing on the A-section increases. Since the voltage swing has been increased at the plate, C645 will have to discharge more to bring the B-section into conduction. If this condition exists, the B-section will be returned to cutoff later, resulting in a wider gate output. Thus, the time of the trailing edge can be varied in two ways by adjusting either R1655 or R1657. In actual practice, the TRIGGER ADJUST control R1655 is used to set the square wave duration at 160 nautical miles when the RANGE STROBE POSITION control R1657 is at its maximum value. Since the grid side of R1657 is somewhat sensitive and is physically somewhat remote to the circuit, its lead requires shielding.

d. The only output of the stage is a negative square wave from the A-section plate. The output (fig 17(2)) goes negative at the time of the input pulse from the pulse transformer and goes positive as determined by the position of the RANGE STROBE POSITION control R1657. The output is differentiated by C646, R686, and R687. The variable position pulse triggers the strobe blocking oscillator V613 and the A-gate multivibrator V622 when S609 is set to EXPAND. The differentiated waveform seen at TP604 is shown in figure 17(3).

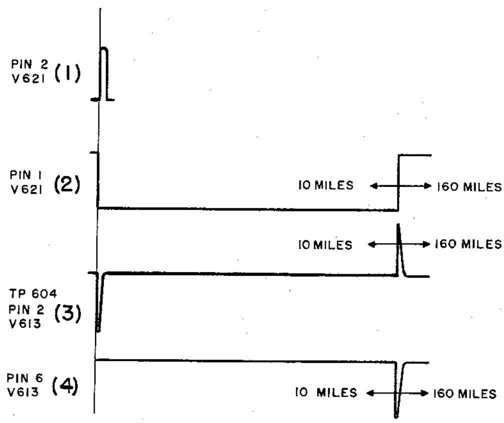

Figure 17. Strobe marker channel waveforms.

36. STROBE BLOCKING OSCILLATOR V613

a. The strobe blocking oscillator V613 is fired once for every PPI sweep by the positive trigger from the strobe multivibrator. The output from the stage is a negative marker pulse (fig 17(4)) that is applied to the IFF-STROBE mixer V601, which in turn applies it to the

PPI. V613A operates as a keyer tube to trigger the B-section, which is the actual blocking oscillator. Each grid is tied to the center of the voltage divider R687 and R688, which applies a negative 26 volts on each grid to keep both sections cut off.

b. The positive trigger is coupled to the grid of the A-section, causing it to conduct through the primary winding terminals 6 to 5 of T601. The A-section winding is wound in the same direction as the winding in the plate circuit of the B-section but opposite to the winding in the grid circuit of the B-section. Therefore, the voltage drop across the A-section plate coil is transformer-coupled to the grid of the B-section, making it more positive and increasing its conduction. The increased conduction continues until the B-section approaches saturation. When the conduction stops increasing, the induced field from the center winding to the grid winding decreases, which causes the positive potential on the grid to decrease, so cutting down the B-section conduction. The induced field about the plate winding then collapses, driving the grid negative. The conduction of the section is further reduced, causing the magnetic field about the center winding to completely collapse and driving the grid to a greater negative value until the section is cut off. Once the B-section starts to conduct, the A-section loses control and has no part in the operation until it is retriggered. The A-section conducts for the duration of the applied trigger, 2 microseconds, and returns to its normally cutoff state. During the back swing of the operation, a negative potential across C626 holds the B-section at cutoff to prevent the blocking oscillator from being retriggered by oscillations in T601 or a continued conduction of the A-section. The negative potential on C626 discharges through R687 to its original value of 26 volts before the next trigger pulse is applied.

c. The complete action takes only a few microseconds, and the conduction causes a momentary drop in the voltage across the B-section plate-load resistor R685. The voltage, representing the strobe marker, is coupled to the IFF-STROBE mixer V601. At the time the blocking oscillator is triggered by the delayed trigger from the multivibrator, one marker is produced for every sweep. The position of the marker on the PPI will indicate the total delay of the multivibrator. The intensity of the strobe is made variable by the STROBE INTENSITY control R685.

Section IV. TROUBLESHOOTING

37. A-SCOPE CIRCUITS

a. Malfunctions occurring in the A-scope circuitry are usually caused by the following:

(1) Failure of the scope to conduct.

(2) No input trigger.

(3) Failure of the sweep channel to generate a sawtooth voltage.

b. The symptom that indicates the nonconduction of the scope is the absence of the spot at the left of the screen when the INTENSITY control R1693 is turned clockwise. The most common reason for nonconduction is a lack of aquadag voltage (DO NOT ATTEMPT TO MEASURE) caused by a loose lead or faulty power supply. A low intensity setting or a

faulty cathode-ray tube will give no spot intensity. If spots are absent from both indicators, the high-voltage rectifiers (V626), the filament supply, and the interlocks of the indicator, receiver-transmitter, and power supply should be checked. In the case of poor focusing, either the 300 volts or the 450 volts can be too low, so the dc voltages of the power supply should be checked and adjusted before making incorrect assumptions about the scope operation.

c. If the scope conducts but the sweep baseline is not presented when the transmitter is energized, the A-sweep circuits must be checked. The presence of the trigger pulse can be checked at the grid of V622 with a synchroscope. If the trigger is absent, the multivibrator will not be started into operation. With the trigger present, make a synchroscope check at TP609 for a positive square wave and at TP610 for a positive sawtooth voltage. If V624 is bad, the sweep will not exist and the electron beam will be centered on the screen. If V624B is faulty, the sweep will be deflected to the right; if V624A is faulty, the sweep will be deflected to the left.

38. PPI CIRCUITS

a. PPI malfunctions can be listed under the same three categories as for the A-scope. If the spot does not appear at the center of the screen, checks should be made of the aquadag voltage (DO NOT ATTEMPT TO MEASURE), the high-voltage power supply, interlocks, and intensity control circuits. If the 300 and 450 volts are low, the PPI spot will be defocused.

b. The absence of the PPI sweep when the transmitter is turned on can be determined in the same manner as for the A-sweep. First, check for an input trigger to the grid of V603A, and if the trigger is present, continue to the test points in the sweep channel. At TP601 the correct synchroscope waveform will be a positive square wave, at TP602 a positive-going sawtooth voltage, and at TP603 a positive-going voltage waveshape. By using the test points, an isolation of faulty stages can readily be made.

39. RANGE STROBE CHANNEL

The range strobe channel indicates two obvious symptoms if operating improperly. If the EXPAND sweep cannot be obtained on the A-scope and the strobe is not on the PPI sweep, either the multivibrator is faulty or the trigger pulse is missing. If a sweep occurs on the A-scope in EXPAND and the strobe marker is not present on the PPI, the circuitry of V613 or V601 is probably the malfunction. When checking for the range strobe on the PPI, be sure that the RANGE STROBE POSITION control R1657 is positioned counterclockwise to bring the strobe marker to a decreased range.

Section V. SUMMARY

40. A-SCOPE SWEEP CHANNEL

a. The A-scope sweep multivibrator V622 provides the positive unblanking voltage and the negative gate with each input trigger from the pulse transformer T502 or, in the EXPAND sweep, the trigger from the strobe multivibrator V621. The duration of the two

output signals represents the number of microseconds necessary to display 10, 30, 40, 80, and 160 nautical miles, and the sweep range is determined by the position of the A-scope RANGE SELECTOR switch S609. The unblanking voltage is used to intensify the A-scope during the sweep time, and the negative gate is the input to trigger the remaining sweep-generating circuits.

b. The sweep generator V623 produces a positive-going sawtooth voltage during the time of the negative gate input from V622. The sawtooth voltage rises linearly to give an accurate range determination on the screen. From the sweep generator, the sawtooth voltage is amplified by the sweep-inverter amplifier V624. The two outputs from V624 are sawtooth voltages identical in amplitude but opposite in polarity. The positive sawtooth is applied to the right horizontal deflection plate and the negative sawtooth to the left horizontal deflection plate and the negative sawtooth to the left horizontal deflection plate. The result of the push-pull voltages is the left-to-right horizontal deflection of the electron beam across the screen of the scope.

41. PPI SWEEP CHANNEL

a. The PPI sweep channel is triggered by the input pulse from the pulse transformer and generates desired sweep ranges of 20, 40, 80, or 160 nautical miles. The PPI sweep multivibrator V603 is triggered at the time of the transmitter firing and generates a negative gate for the sweep circuits and a positive gate for unblanking the PPI. The negative gate is applied to the sweep generator V605, which develops a sawtooth voltage that is the initial step in making the needed trapezoidal voltage to cause a radial PPI sweep.

b. The final sweep amplifiers, V606 and V608, amplify and shape the sawtooth voltage into a trapezoidal voltage that is applied to the deflection coil L601. This voltage causes a sawtooth of current through the coil and deflects the electron beam from the center to the outside of the PPI screen. For azimuth resolution, the deflection coil is rotated in azimuth by a synchro system that is connected to the antenna rotation.

42. STROBE MARKER CIRCUITS

The strobe delay multivibrator V621 generates a delayed trigger for the A-sweep multivibrator in the EXPAND position and for the strobe blocking oscillator V613. V621 is triggered by the pulse from the pulse transformer. Its output is a negative gate with the trailing edge made variable in time by the RANGE STROBE control R1657. The trailing edge is variable from 10 to 160 nautical miles. After the gate is peaked, the trailing edge is the delayed trigger. The strobe blocking oscillator V613 is triggered by the delayed trigger and produces the strobe marker for the PPI sweep. The negative strobe pulse is applied from the blocking oscillator to the IFF-STROBE mixer V601. It is then applied to the cathode of the PPI as a negative signal that intensifies the PPI sweep.

Section VI. QUESTIONS

43. A-SCOPE SWEEP CHANNEL

a. How many different sweep lengths are possible for the A-scope? What is the sweep length display of each in microseconds?

b. List the components that determined the 160-mile gate duration.

c. Compute the fixed bias on grid, pin 2, of V622A.

d. What component determines the electrical length of the sweep?

e. What is the purpose of the SLOPE control R1676?

f. How is a sawtooth voltage formed at the output of V623 when the input is a negative square wave?

g. Draw the two outputs of V624. Where are they applied?

h. What is the indication of the A-scope screen if V624 is faulty?

i. What is the purpose of the unblanking voltage at the A-scope?

j. If the sweep is positioned too far to the right, what control is used to correct it?

44. PPI SWEEP CHANNEL

a. Why are C610 and C611 placed in parallel in the plate circuit of V603A when the range is switched from 20 to 40 miles?

b. What is the only control that varies the amount of time that V603B is cut off?

c. Why are the cathodes of V606A and V608 connected?

d. How is the unblanking voltage decreased at the longer sweep ranges?

e. What is the purpose of V607A and its associated plate resistor circuit?

45. STROBE MARKER CHANNEL

a. What initiates the action of V621?

b. What is the minimum delay in nautical miles of the multivibrator?

c. When the RANGE STROBE POSITION control R1657 is turned fully clockwise, where should the strobe marker appear on the PPI screen? What control should be used to compensate for an inaccurate strobe position?

d. Where are the two outputs appled from V621?

e. If the EXPAND sweep appears on the A-scope but the strobe marker is not on the PPI, which stage or stages should be checked?

CHAPTER 4

RANGE MARKER CHANNEL AND MARKER SWITCHING

Section I. BLOCK DIAGRAM OF THE RANGE MARKER CHANNEL

46. PURPOSE

The range marker circuit produces signals with a time interval that is representative of a definite radar range. The signals are displayed as positive pips on the A-scope sweep baseline and as intensity modulated spots on the radial sweep of the PPI. With the presence of range markers on the presentation screens, the position and range of target echoes can be compared with the position of the range markers, and the target range can be determined. The AN/TPS-1G uses a 5-mile spacing between successive range markers when the sweep ranges are 20 and 40 nautical miles, and a 25-mile spacing for the 80- and 160-nautical mile sweeps. On the 80- and 160-mile sweeps, 5-mile markers of lesser amplitude can be placed between the 25-mile markers by holding the RANGE MARKS switch to the TEST position.

47. MARKER GATE MULTIVIBRATOR V614

The marker gate multivibrator V614 is a start-stop multivibrator that is triggered by the same trigger that initiates the scope sweeps at time zero. The output of the multivibrator is a negative-going square wave gate that goes negative at time zero and remains negative for approximately 2,000 microseconds. The width of the negative gate can be varied by means of a potentiometer in the plate circuit of the output section. This negative gate is applied to the control grid of the marker oscillator V615A.

48. MARKER OSCILLATOR V615

The range marker oscillator V615 is a Hartley-type oscillator that is gated (permitted to oscillate) by the negative square wave from the marker gate multivibrator. The output of the oscillator is a sine wave whose first cycle goes negative at time zero. The frequency of the sine wave is slightly above 16 kc, which gives a period of 61.9 microseconds, the necessary microseconds to represent 5 nautical miles. The sine wave output is applied to the control grid of the marker amplifier V616A.

49. MARKER AMPLIFIER V616

The 16-kc sine waves are applied to the grid of the peaker amplifier V616A. By employing cutoff limiting, the output waveform is limited, giving the effect of squaring off of the original sine wave. The output is a positive-going square wave at 5-nautical mile intervals and is coupled to the grid of V616B. V616B acts as the keyer stage for the 5-mile blocking oscillator V616A. The positive square wave at the grid of V616B causes it to produce a negative trigger that is transformer-coupled as a positive signal to the grid of V617A.

50. 5-MILE BLOCKING OSCILLATOR V617

The 5-mile blocking oscillator produces a negative pulse at its plate and a positive pulse at its cathode for each input from V616B. The pulses occur simultaneously in time and are spaced at 5-mile timing intervals. The negative pulses from the plate circuit are applied to the PPI through S606D and V602. The positive pulses from the cathode are applied as two separate inputs:

a. One to the A-scope through S608C to receiver video channel.

b. The other to the control grid of V617B.

51. 25-MILE BLOCKING OSCILLATOR V617B AND V618B

The positive output signal from the cathode of V617A, the 5-mile blocking oscillator, is applied to the grid of V617B, which functions as a keyer tube for the 25-mile blocking oscillator. The positive pulses from V617A are a series of 5-mile range markers; every fifth pulse of this series of pulses is used to trigger the 25-mile blocking oscillator V618B. In order for every fifth pulse of the 5-mile markers to trigger the 25-mile range marker oscillator, a countdown circuit must be incorporated. This function is accomplished in the grid circuit of V618B by biasing the tube well beyond cutoff and superimposing the positive 5-mile markers upon the charging curve of the grid circuit (capacitor). The grid of V617B thus sees the charging curve of the grid capacitor progressing in a positive direction as shown in Figure 18(1). The countdown action is accomplished by adjusting the slope of the charging curve so that each fifth 5-mile marker will cause V618B to conduct, producing one 25-mile marker and simultaneously returning V617B to the original cutoff condition. The 25-mile markers from V618B are applied to both scopes on the 80 and 160 nautical mile sweep ranges. The output of V618B at the plate is a negative marker for the PPI: positive pulses from the cathode form the 25-mile markers for the A-scope.

Section II. DETAILED DISCUSSION—RANGE MARKER CHANNEL

52. RANGE MARKER MULTIVIBRATOR V614

The marker gate multivibrator V614 is a start-stop, cathode-coupled multivibrator that produces a negative-going square wave beginning at time zero. The signal initiating the negative gate is the same positive 13-volt pulse that triggers the range strobe, A-scope, and PPI sweep circuits. The positive pulse originates at the pulse transformer and is reduced in amplitude by R680 and R681. It is always present at the control grid of V614A when the transmitter is turned on. When the RANGE MARKS switch S608A is set to ON or TEST, the A-section grid voltage is placed at +51 volts as compared with zero volts when S608A is set to OFF. V614A is cut off at all times unless a trigger input comes from the pulse transformer in the transmitter unit. The switch in the ON or TEST position raises the grid level so that each trigger will cause V614A to conduct. Since the B-section grid is tied directly to B+ through a 3.5-megohm resistor, that section will conduct unless a negative signal is applied to its control grid. The conduction of the B-section develops approximately +75 volts across R698 and R699, causing a bias of about 24 volts on the

A-section, which holds it cut off. The positive trigger applied to the A-section grid causes the section to conduct and results in a drop of plate voltage. When the RANGE MARKS switch S608A is OFF, the A-section grid voltage is zero and the cathode voltage caused by the B-section conduction makes a bias of about 75 volts on this section, keeping it cut off during the positive trigger pulse input. Therefore, there will never be conduction of the A-section if the switch is in the OFF position. When S608A is in ON or TEST position and the A-section is made to conduct by the positive trigger input, the drop in plate voltage is coupled to the control grid of the B-section through C628 and to the control grid of the marker oscillator through C629. This drop in voltage at the B-section grid cuts it off until C628 discharges toward B+ through R697 to the point where the B-section will again begin conduction. The time for C628 to discharge sufficiently for the B-section to conduct is approximately 2,000 microseconds. As soon as the B-section starts conducting, the A-section is again cut off by the cathode bias across R698 and R699. This gives a rise in the plate voltage to B+, which is coupled to the grid of the marker generator through C629. The output of the marker multivibrator is a negative square wave, 120 to 150 volts in amplitude, that goes negative at time zero and remains negative for approximately 2,000 microseconds. The width of the marker gate may be varied by the MARKER GATE control R691, which varies the amplitude of the voltage drop at the A-section plate. The greater the voltage drop, the longer it will take C628 to discharge to the point where the B-section will conduct. The negative square wave output of V614 is monitored at TP605.

53. MARKER OSCILLATOR V615

The marker oscillator is a Hartley-type oscillator consisting of V615B and the tuned circuit Z601. V615A provides the switch for turning the oscillator on and off. Under a no-signal condition, V615A and B are conducting and Z601 cannot oscillate. The A-section obtains cathode self-bias through R1610. The B-section cathode bias is the result of voltage dropped across R1611. The result of the two constant currents through the L-section of Z601 keeps the tank from oscillating and charges the capacitor negatively on its ground side. The negative gating voltage from the marker multivibrator is applied to the grid of V615A cutting it off. When the current through the inductance of Z601 is reduced, magnetic lines of force about the coil collapse, causing current to flow from S to T to F and charging the capacitor negatively at its cathode side. Since V615A is cut off, the only path for current flow is the LC circuit of Z601, tuned to resonate at approximately 16 kc. The first cycle goes negative at time zero due to the initial charge on the capacitor and the collapsing field about the coil. After the first negative swing, the capacitor again discharges through the coil to give a positive half-cycle output. The oscillations will attenuate rapidly unless a positive feedback to the tank circuit is available. The oscillating signal from Z601 is applied to the control grid of V615B and the output signal to V616A. For every negative swing, V615B is cut off and allowed to conduct only during the positive half-cycles. When V615B conducts, current drawn through the centertap of the coil in Z601 adds to the current that is in the tank circuit to sustain oscillations. The increase in current is limited by R1611, so that the oscillations will remain at a constant amplitude. Since V615B is cut off on the negative swings, its operation is class C, which is typical of a Hartley oscillator that works most efficiently with this type of biasing. However, the output is taken from pin E of Z601 and will be a sine wave. The output frequency of 16 kc is such that every cycle will represent 61.9 microseconds or 5 nautical miles. The sine wave output is applied to the control grid of the marker amplifier V616A.

54. MARKER AMPLIFIER V616

The sine wave output of Z601 is applied to V616A and B, which converts the signal into a trigger for every cycle. The two sections of V616 have a common cathode load R1614 with a positive 24-volt potential developed across it. The A-section grid, connected directly to the cathode of V615A, has a positive 13 volts directly coupled to it during a no-signal condition. With the beginning of the negative swing from the oscillator, V616A is driven rapidly to cutoff and the negative swing is clipped and squared at the output. On the positive swing at the grid, the grid current limiting resistor R1612 squares off the positive signal at the grid and gives a negative square swing at the output. The negative input, which is the positive output, is the most important because it is used to give the 5-mile marker display. When V616A is cut off, its plate coil L604 tends to keep current flowing in the same direction and produces a high-voltage peak that rises above B+. This peak in voltage adds to the normal rise in plate voltage, placing the grid of V616B at a high positive potential. At the same instant that V616A is cut off, the cathode potential of V616B decreases because of the decrease in current through R1614. The net result at V616B of the high positive signal at the grid and the decrease in the positive cathode potential is a surge of current flow through the tube and the terminals 6 to 5 of T602. The increase of current through terminals 6 to 5 of T602 causes the voltage to decrease at the plate of V616B. The current flow through T602 induces a positive trigger at terminal 2 of T602 that is used to trigger the 5-mile blocking oscillator V617A.

55. 5-MILE BLOCKING OSCILLATOR V617A

The 5-mile blocking oscillator V617A is a driven blocking oscillator which remains cut off until a positive input is applied to its grid. Cutoff bias is obtained from the grid resistor network R1622, R1623, and the negative 150-volt supply. The voltage divider places the grid at a negative 26 volts holding the stage cut off under a no-signal condition. Both the positive and negative peaked signals are coupled from V616B through T602 to the grid of V617A. Since V617A is already at cutoff, only the positive signals at the grid will trigger the oscillator. At time zero when V616B conducts, the induced voltage at the grid, pin 2, of V617A is positive, and the tube conducts. The conduction causes current flow through terminals 8 to 3 of T602, which induces a greater positive signal at the V617A grid end of T602. This causes increased conduction of V617A, and the conduction through T602 accumu lates until the tube approaches saturation, nearly instantaneously. With V617A conducting, the grid current flow charges C635 negatively, almost at the point of tube saturation, the current flow through T602 ceases to change, and the magnetic field around the plate coil no longer expands. Since there is no voltage induced in the grid coil, the field about the coil will collapse to give a negative voltage on the grid of V617A. Current through the tube will rapidly decrease, and cutoff bias will be developed. With no grid current flow, C635 discharges through R1622 to ground, placing the control grid below cutoff. Between the triggering pulses, C635 is completely discharged so that the grid is returned to a negative 26-volt potential when the next trigger occurs (after 61.9 microseconds). There are three outputs from V617A, all occurring simultaneously when the tube is made to conduct. The output from the plate is negative signals that appear at 5-nautical mile (61.9-microsecond) intervals. The plate output is applied to the PPI VIDEO and RANGE MARKER MIXER V602 via S606D. The two positive outputs are developed across R1621 in the cathode of V617A when the tube conducts. One of these outputs is applied to the control grid of the 25-mile blocking oscillator keyer tube V617B; the other output is applied to the A-scope VIDEO

AMPLIFIER V619B when S609E is set to the EXPAND, 20-mile, or 40-mile positions. The 5-mile markers appear on both the A-scope and PPI if the RANGE MARKS switch S608 is turned to ON and the sweep displays are 20 or 40 nautical miles. The A-scope displays 5-mile markers for the EXPAND sweep regardless of the PPI sweep range setting.

56. 25-MILE BLOCKING OSCILLATOR V618B AND OSCILLATOR DRIVER V617B

a. For proper operation, the 25-mile blocking oscillator must be triggered by each fifth positive pulse in the train of 5-mile range marker pulses. These positive 5-mile markers are applied to the control grid of V617B, the keyer stage of the 25-mile blocking oscillator. When V617B is triggered by the positive signals, a high-current pulse flows through T603, inducing a positive voltage that is applied to the grid of V618B and triggers the stage.

b. In the quiescent (untriggered) condition, V618B is conducting but is near cutoff. After being triggered, V618B is driven to cutoff by the negative voltage from the voltage divider composed of R165, R1624, and V618A, which is in conduction. The cutoff bias after the stage is triggered is provided by the action of C637.

c. At the instant V617B is triggered by each 5-mile range marker, an increase in current flow occurs through the stage and terminals 6 to 5 of T603. The current flow through T603 induces a positive grid voltage at pin 7, V618B. When the grid of V618B goes positive, the cutoff bias is overcome and current flow begins through the stage and terminals 8 to 3 of T603. This current flow induces an even greater positive voltage on the grid, which drives the stage almost into saturation. Near the point of saturation the current-flow change in T603 stops, and the magnetic field about T603 collapses to give a negative potential on the grid of V618B. The negative voltage swing on the V618B grid immediately causes the tube to cut off, ending the first cycle of operation. This first cycle occurs at the time of the first input 5-mile marker or at radar time zero. The outputs for the first cycle of operation are a positive signal from the cathode of V618B and a negative output from the plate of V618B.

d. Reference has been made to C637 charging as the voltage across its terminals approaches zero. This term is used because the positive plate of the capacitor is grounded, and the change in potential of the negative plate with respect to ground follows the type of exponential rise normally associated with charging. This action is often referred to as "charging toward zero." V618B is cut off by the collapse of the magnetic field about T603 after its first cycle of operation, and the charge of C637 keeps V618B cut off. During the conducting time of V618B, C637 was charged negatively in respect to ground. When V618B is cut off, C637 "charges toward zero" through R1619, R1630, and the BLOCKING OSCILLATOR ADJ R1618 into the power supply (fig 18(1)). The time constant, or charging rate, is variable by the BLOCKING OSCILLATOR ADJ R1618 so that the blocking oscillator bias can be kept below cutoff during the occurrence of the first four of each set of five 5-mile range markers. The inputs from the 5-mile blocking oscillator occur 61.9, 123.8, 185.7, 247.6, 309.5, and 371.4 microseconds after the first 5-mile input and represent ranges of 5, 10, 15, 20, 25, and 30 nautical miles. For proper operation every fifth 5-mile marker must be used to trigger V618B. As seen in figure 18(2), R1618 can be set for a decreased resistance and discharge time constant that will cause the tube to be triggered by the fourth 5-mile marker. However, this setting makes the triggering occur every 20 miles and is not desired. From the same figure, it can be seen that the correct setting of R1618 is the

point where the discharge of C637 will permit the tube to be triggered by the fifth 5-mile marker. In this manner range marker spacing of 25 nautical miles is obtained from V618B. After the fifth 5-mile marker has triggered V618B, the complete charging and discharging of C637 is accomplished so that 25-mile range markers are available in the 80 and 160 nautical mile sweep ranges. C637 will never have to discharge for one time constant to give the triggering action. The important point is that R1618 provides a means of properly setting the blocking oscillator for stable 25-mile markers.

e. The stage V618B has two outputs upon conduction. A negative output from the plate is applied to the PPI video and range marker mixer V602 through S606D, when it is set for the 80- and 160-nautical mile sweeps. A positive output from the cathode is coupled through R1628 to the A-scope video amplifier V619 when S609E is set for the 80- and 160-mile positions. Both outputs occur simultaneously and will represent 25-mile intervals, 309.5 microseconds, if the BLOCKING OSCILLATOR ADJ control R1618 is properly adjusted.

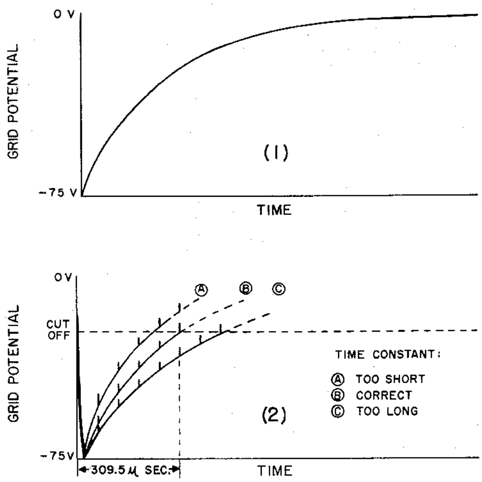

Figure 18. Countdown of V618B.

f. It is possible to reconnect the output circuitry of V617A and V618B to give 10-mile markers instead of 25-mile markers. But, because 10-mile markers are not used by the Army, their generation will not be discussed in detail in this text. The 10-mile markers are made possible by making the following connections: terminal B to D; terminal C to A; and terminal D to Z. These connections produce a bias on both V617A and V618B to give an output for every other 5-mile trigger pulse. R1618 can still control the timing of the 10-mile range markers.

57. DC RESTORER V618A

The grid circuit of the 25-mile blocking oscillator V618B is connected to a dc restorer V618A, which provides a clamping action for the bias on V618B. When restorer V618A is conducting, it places a negative potential on the grid of V618B, but this potential itself is not sufficient to keep the blocking oscillator cut off during input 5-mile triggers. At the

time V618B conducts and during the initial charging of C637, the negative potential on the plate of V618A will keep it completely cut off. By having V618A cut off, the only possible charge path for C637 is through R1619, R1630, and R1618 to the B+ power supply. If C637 were permitted to charge completely, it would be charged through zero to the positive 300-volt level, destroying the countdown feature of the blocking oscillator. This complete charge is not possible, however, because V618A will conduct when C637 has charged to a potential where the V618A plate is more positive than its cathode. The grid voltage is thus clamped at a specific level, and C637 will retain the same minimum charge throughout every cycle of operation. The operation of the clamper and C637 enables the correct count-down of the blocking oscillator by the proper adjustment of the BLOCKING OSCILLATOR ADJ control R1618.

Section III. RANGE MARKER SWITCHING

58. RANGE MARKS SWITCH S608

a. The RANGE MARKS switch S608 is a ganged 3-section switch that turns the range markers on and off and correctly applies them to the A-scope and PPI for the different sweep ranges. The A-section of the switch is connected in the grid circuit of the range marker multivibrator V614 for turning it on or off. With the switch in the ON or TEST position, the positive 300 volts is applied to the voltage divider network R689 and R690, which places a positive 51 volts on the grid, pin 2, of V614. This raises the bias to a level where the input triggers can cause V614A to conduct. When the switch is set to the OFF position, the potential on the grid of V614A is zero and, since V614B is conducting, the cathode is at approximately 75 volts, which keeps the A-section of the tube cut off. It is S608A that makes possible the initial generation of range markers.

b. S608B operates in conjunction with the RANGE SELECTOR switch S606D and S606E to impress range marks on the cathode of the PPI V609. S608C works with the RANGE SELECTOR switch S609E to apply the range marks to the A-scope screen. The discussion of the two switches will be included in the discussion below because their operation is accomplished jointly.

59. S608B AND S606D/E

a. 5-mile range markers. The plate output of the 5-mile blocking oscillator V617A is coupled through C634, R1616, and the 5-10 MILE MARKER INTENSITY control R1617 to S606D. The amplitude of the negative 5-mile markers can be varied by the intensity control R1617. After passing through the intensity control, the markers are present at S606D in the 20- or 40-nautical mile sweep range. S606D, when placed to the 20- or 40-mile position, applies the markers directly to the PPI video and range marker mixer amplifier V602, which mixes the range markers with the radar video and applies them to the PPI cathode as negative signals. The 5-mile markers then are present on the PPI under the following switching arrangements: PPI RANGE SELECTOR switch S606 to 20 or 40 miles, RANGE MARKS switch S608 to ON or TEST. The B-section of S608 has no significance in the OFF position, but remember that S608A did not permit range markers to be generated. S606E, in the 20- or 40-mile position, shorts to ground all 25-mile range markers that appear from the output of V618B.

b. 25-mile range markers. In the 80- and 160-mile sweep ranges the desired range markers are at intervals of 25 miles and are switched into the PPI video circuit by S606D and S606E. The negative 25-mile range marker output from the plate of V618B is coupled through C638, R1632, and the 25-10 MILE MARKER INTENSITY control R1629 to S606D. The 25-mile markers are applied directly to the cathode of V602 through S606D. The 5-mile range markers are shorted to ground through S608B set to ON and S606E set to the 80- or 160-mile position. Where S608B is set to the TEST position, 5-mile markers are also applied along with the 25-mile markers. The 5-mile marks are of decreased amplitude in respect to the 25-mile markers due to the decreased current through R1633. When S608 is set to TEST, four 5-mile markers should appear between each pair of 25-mile markers.

60. S608C AND S609E/F

a. 5-mile range markers. The positive 5-mile range markers from the cathode of V617A are applied to S609E and through S608C to S609F. With S609 set to the 20- or 40-mile position and S608 set to ON, the 5-mile markers are applied through S609E to the A-scope video amplifier V619B and finally to the top vertical deflection plate of the A-scope for display. S609E simply affords a direct path between V617A and V619B. S609F shorts the 25-mile markers to ground in the 20- or 40-mile position. In the 20- or 40-mile position, S608C has no function in the ON position, but is ganged to S608A to start the markers. For 5-mile markers, the setting of the switches is as follows: A-scope RANGE SELECTOR switch S609 to 20 or 40 miles, RANGE MARKS switch S608 to ON or TEST.

b. 25-mile markers. The positive 25-mile marker output of V618B is applied through R1628 to S609E in the 80- and 160-mile positions. S609E provides a direct path for the 25-mile markers to the A-scope video amplifier V619B. S609F shorts out the 5-mile markers that are applied through the ON position of S608C. In the TEST position of S608C, the 5-mile markers are coupled through S608C and R1634 to the A-scope video amplifier and appear smaller in amplitude than the 25-mile markers on the A-scope screen. In this TEST position, the 5-mile markers are not shorted to ground.

c. Range markers in EXPAND sweeps. For the A-scope EXPAND sweep range, the range markers for the PPI are not affected, but those on the A-scope will always have an interval of 5 miles. The 5-mile markers are switch to the A-scope from V617A to the EXPAND position of S609E. S609F shorts the 25-mile markers to ground. No more than two 5-mile range markers are visible on the expanded A-sweep.

Section IV. MISCELLANEOUS CIRCUITS OF THE INDICATOR

61. FILAMENT SUPPLY

a. The filament supply for the tubes within the indicator comes from the 115-volt ac supply through F404 and the filament transformer T605. The secondary windings of 4 to 3 on T605 provide 6.3 volts ac for indicating lamps and filaments. The POWER ON lamp I609 is lighted by 6.3 volts applied when the SYSTEMS POWER is turned ON. Eight lamps, I601 through I608, lie around the PPI tube face for illuminating the azimuth scale. The lamps are in parallel, and their brilliance is controlled by the DIMMER potentiometer R2617, which controls the voltage to the lamps.

b. The tubes that have the filament voltage of 6.3 volts ac on pins 3 and 4 are V601, V602, V604, V605, V607, V611, V620, and V623. The filament voltage is applied to pins 2 and 7 of V608 and V610. The tubes that contain two sections and filaments for each section are V603, V606, V612, V613, V614, V615, V616, V617, V618, V619, V621, V622, and V624. Filament voltage is parallel to pins 4 and 5, pin 9 being a common ground for both sections of the filament circuit.

c. The secondary windings of terminals 7 to 8 furnish 6.3 volts ac to the filaments of the A-scope cathode-ray tube V625. The 6.3 volts ac rides on a -1,500-volt reference to prevent arcing between the cathode and filament elements of V625. Terminals 5 to 6 of T605 give 6.3 volts ac for the PPI tube filaments. This voltage is referenced on a positive potential that is determined by the COARSE INTENSITY and INTENSITY controls.

62. SYSTEMS GROUND AND PHONE JACKS

a. Ground. The units of the radar are connected by a common ground with the indicator ground connected from pin 45 of J601 to pin 45 of J407.

b. Phone jack J602. Three telephone jacks are located on the radar for remote intercommunication between units. If the indicator is at a distance from the remainder of the radar, a telephone connection is necessary because the indicator screens must be observed in adjusting the receiver and MTI circuits. Phone jack J602 makes possible the connection from the indicator to the power supply J410 and the antenna base J752.

63. HEATERS

For cold temperature operation, one thermal-controlled heater HR601 is included in the indicator. This heater is connected to the 115-volt ac heater power supply in parallel with the remaining unit heaters. S611 is the thermal control switch that opens the ac line at 15° C and recloses the line at 0° C. When the line is opened, the heater element is disconnected.

Section V. TROUBLESHOOTING, SUMMARY, AND QUESTIONS

64. RANGE MARKER CHANNEL

a. Troubleshooting the range marker channel is readily accomplished because the symptoms of malfunctions quickly isolate the faulty stages. If a realization of the symptoms of the faulty stage is obtained, only a logical procedure of troubleshooting is necessary to locate the defective component. When reference is made to a tube, the circuitry about the tube is also included. In checking the range marker circuits, the RANGE MARKS switch S608 must be turned to ON, and the SWEEP SELECTOR switch set consecutively to the 20- 40-, 80-, and 160-nautical mile positions.

b. The range marker multivibrator V614 must have an input trigger to develop a negative gate output. Any of the following malfunctions will cause the loss of both 5- or 25-mile range markers:

(1) No input trigger.

(2) RANGE MARKS switch S608A opened in the TEST or ON position.

(3) V614B always conducting.

(4) Nonconduction of V614A and V614B.

c. The range marker oscillator V615A must receive a negative gate to cut it off and produce a sine wave output. The following are possible indicated malfunctions and their symptoms:

(1) No input from V614A . . . . No range marks.

(2) Z601 defective . . . . No range marks.

(3) V615A not conducting . . . . Free-running and unstable range marks.

(4) V615B not conducting . . . . Damped range marks that disappear after five or six 5-mile markers.

(5) V616A/B not conducting . . . . No range marks.

d. The 5-mile blocking oscillator V617A is normally cut off and requires a positive signal coupled to its grid from V616B through T602. If V617A does not conduct, there will be no 5-mile range markers on the scope screen and the 25-mile blocking oscillator cannot be triggered. If the negative 150 volts is removed from the fixed grid bias circuit, the range markers will be unstable and free running.

e. The 25-mile blocking oscillator V618B and its driver V617B are isolated by the symptoms noted on the scopes. If the 25-mile range markers are not available in the 80- or 160-mile sweep ranges, V617B and V618B should be checked. If the range markers are not stable or appear at the incorrect range interval (as determined by S608 set to TEST), the BLOCKING OSCILLATOR ADJ control R1618 may be misadjusted.

65. SUMMARY

The range marker channel provides range markers for the A-scope and the PPI. In the 20- and 40-mile sweep ranges, 5-mile range markers are available for display; in the 80- and 160-mile sweep ranges, 25-mile markers are displayed. The range markers are generated by placing the RANGE MARKS switch S608 at either the ON or the TEST position. In the TEST position, smaller amplitude 5-mile range markers appear between the 25-mile markers. The range markers are synchronized in time with the sweep generator circuits by the input sync trigger from the pulse transformer in the transmitter. The 5-mile markers are generated from a Hartley oscillator with a frequency slightly over 16 kc, which gives marks correctly spaced. The 5-mile markers are used for display as well as to trigger the 25-mile range marker blocking oscillator. The 25-mile markers appear for every fifth 5-mile marker.

66. QUESTIONS

a. When does the first range marker appear on the screens?

b. What triggers the range marker channel?

c. How is V614 kept from free-running with the RANGE MARKS switch turned OFF?

d. What is the resonant frequency of Z601 and the range represented by one cycle?

e. What is the purpose of V615B in the oscillator operation?

f. What is the fixed grid bias on V617A?

g. Briefly discuss the charging and discharging path of C637 including its purpose.

h. What does S609F accomplish in the 20- and 40-mile positions?

i. What is the indication that the BLOCKING OSCILLATOR ADJ control R1618 is adjusted correctly?

j. There are only five 25-mile range markers on the 160-mile sweep range. What is the needed adjustment?

CHAPTER 5

INDICATOR POWER SUPPLY AND INDICATOR ADJUSTMENT PROCEDURE

Section I. OPERATION OF THE HIGH-VOLTAGE POWER SUPPLY

67. ADJUSTMENTS

a. Specific voltages are required to insure the proper operation of any electronic unit. The indicator scopes need high dc voltages for the generation of the electron beams within the display scopes. Since the aquadag voltage is extremely high, the high-voltage power supply that provides the voltages above the 450-volt dc level for the A-scope and the PPI is located within the indicator unit to minimize insulation in cabling.

c. The indicator adjustments must be understood and correctly performed in order to have the scopes present accurate target data. Each adjustment must be analyzed to give a better understanding of the overall field adjustment of the indicator.

68. VOLTAGES

a. The A-scope uses four different outputs from the half-wave rectification of V626. The aquadag voltage is +1,500 volts; the control grid supply is a -1,500 volts. The INTENSITY control R1693 is connected through a voltage divider to the -1,500 volts, but, with the control, the cathode voltage is made variable from -1,380 to -1,470 volts. The focusing anode is connected to the same voltage divider network of -1,500 volts, the FOCUS control R1696 making the limits of the focusing voltage adjustable from -856 to -1,170 volts. For A-scope operation, the source voltages from the indicator power supply are +1,500 volts and -1,500 volts. The smaller negative voltages are supplied from the -1,500 volts by a voltage divider network. It should be remembered that the +300 and +450 volts dc originate in the power supply unit and are not the output of V626 circuitry.

b. The PPI requires two outputs, one for the aquadag and one for the accelerating anode. The aquadag potential is +8,000 volts, which is the highest voltage requirement of the indicator power supply; +700 volts, obtained from the 500-volt supply through a voltage divider, is applied to the accelerating anode in the PPI. The +300 and +450 volts that are used at the A-scope and the PPI are also outputs from the power supply unit of the radar.

69. V626 OPERATION

a. The half-wave rectifier circuit consists of T604, V626, and the cathode and plate resistive loads. The primary voltage at terminals 2 to 1 of T604 is 115 volts ac. This voltage induces a much higher potential into the secondary, the secondary peak voltage being approximately 13,300 volts across terminals 3 to 4. The rectifier will conduct for each positive half-cycle at terminal 4 and the plate of V626. When V626 conducts, the cathode current will flow from ground through R2603, R2604, R2606, R2607 through R2614 in series, and through R2615, developing +5,000 volts at the junction of R2614 and R2615. At the same time, the plate current flows from the plate through T604, R1692, R1693, R1694, R1695, R1696, R1697, and R1698, developing -1,500 volts in reference to ground at terminal

H of E602. The negative voltage supply is filtered by C666 and is used for A-scope operation. The positive voltage is filtered by C665 and is used as aquadag voltage for both indicating screens and the acceleration voltage for the PPI.

b. In the negative side of the power supply, the highest potential of -1,500 volts is applied to the control grid of the A-scope. The cathode potential on the A-scope is variable from approximately -1,470 to -1,380 volts. This makes a fixed bias between -30 volts to -120 volts under a no-unblanking signal. The emission rate from the cathode is adjusted by the INTENSITY control R1693, the positive unblanking pulse being applied to the control grid during sweep time. In this manner, uniform brilliance is possible for the sweep displays. The next voltage off the negative resistance network is the focusing voltage from the FOCUS control R1696. This voltage, variable between -1,170 volts and -856 volts, sets up the proper electrostatic focusing field, so that the electron stream will converge at one point on the A-scope screen. The negative voltage monitored at TP611 should indicate about -425 volts dc.

c. The outputs from the positive side of the rectifier (the cathode circuit) are used as aquadag potentials. The highest potential of +8,000 volts is filtered by C667, R2624, and C668 and is applied to the aquadag coating of the PPI. The positive aquadag voltage removes the electrons that are due to secondary emission. Plus 1,500 volts is placed on the A-scope aquadag coating through terminal K of E602. The +1,500 volts is developed across a portion of the same resistors that were present in the +5,000-volt development. The accelerating voltage for the PPI, originating from the same positive side of the rectifier, is +700 volts taken across R2603 and R2604. The accelerating voltage is coupled through terminal L of E602 to pin 3 of V609. The positive voltage supply is monitored at TP612 for an approximate reading of +270 volts dc.

d. The high-voltage power supply is used primarily for the aquadag coating of both scopes, and the current drain is very low; therefore, very little filtering is necessary. The only filters, as have been mentioned, are purely RC type, due to the low amount of current drain from the supply.

70. TROUBLESHOOTING

The malfunctions of an inoperative power supply are noted by the absence of an electron trace on the A-scope and the PPI screen, because the loss of the electron stream can be due to the absence of the aquadag voltages on the scopes. Two test points, TP611 and TP612, should be used exclusively for making voltage measurements within the high-voltage supply. Do not touch or tamper with V626 or the aquadag voltages when the set is energized. If further troubleshooting is necessary, remove the power from the radar and continue with resistance (continuity) checks of the supply. MONITOR VOLTAGES ONLY AT TEST POINTS TP611 AND TP612. These test points are at low voltage and low impedance points to minimize loading of the power supply and also as a safety factor for the repairman.

71. OVERALL ADJUSTMENT CONTROLS

The indicator circuits must provide means of adjustment to compensate for variables in construction and aging of the various components. These controls are easily understood and usually can be adjusted quickly. Many faulty components can be isolated by adequate knowledge of each control and how it functions. The complete field adjustments are given in this section.

72. INDICATOR FIELD ADJUSTMENTS

a. Preliminary steps.

(1) Remove the INDICATOR chassis from its case.

(2) Close the INDICATOR INTERLOCK S603.

(3) Be sure the POWER SUPPLY has been properly adjusted before proceeding with the following adjustments.

(4) Set the POWER switch S602 to ON.

(5) Set the RADIATE switch S616 to ON.

b. A-scope and range markers adjustment.

(1) On the SIGNAL COMPARATOR, set OPERATION SELECTOR switch S2354 to REMOTE.

(2) On the INDICATOR, set SYSTEM SELECTOR switch S601 to NORMAL and turn RECEIVER GAIN control R608 fully counterclockwise.

(3) Set RANGE MARKER switch S608 to ON.

(4) Set the A-scope RANGE SELECTOR switch S609 to 160 miles.

(5) Adjust the A-scope INTENSITY control R1693 to produce a distinct sweep on the screen.

(6) Adjust VERTICAL CENTER control R2601 to properly position the baseline vertically on the screen.

(7) Adjust HORIZONTAL CENTER control R1687 so that the baseline will start close to the left side of the screen.

(8) Adjust FOCUS control R1696 and ASTIGMATISM control R1689 for a sharply focused baseline.

(9) Adjust SWEEP LENGTH control R1676 so that the complete baseline will continually appear on the screen.

(10) Hold RANGE MARKER switch S609 in the TEST position. Adjust BLOCKING OSCIL-LATOR ADJUST control R1618 so that four 5-mile markers appear between each pair of 25-mile markers.

(11) Turn A-GATE control R1669 fully clockwise. (This setting insures a baseline length of 160 miles or greater.)

(12) Adjust MARKER GATE control R691 so that the 160-mile marker will appear on the baseline.

(13) Adjust A-GATE control R1669 until the complete baseline displayed is 160 miles, as indicated by the range markers.

(14) Adjust SWEEP LENGTH control R1676 so that the last range marker in each case will appear at the end of the baseline in all four ranges.

(15) Check the baseline in all four ranges to be sure that the baseline does not extend off the screen either to the right or to the left.

NOTE: A baseline extending off the screen indicates either improper adjustment or a malfunction in the sweep circuits.

(16) Check the vertical position of the range markers with respect to the baseline. If the ranged markers are leaning, adjust the A-scope DEFLECTION BALANCE control C659 so they appear perpendicular to the baseline.

(17) Adjust RECEIVER GAIN control R608 to allow approximately one-quarter inch of grass on the screen.

(18) First turn the A-scope VIDEO GAIN control R683 fully counterclockwise, then adjust the control slowly clockwise until the echo signals reach maximum amplitude.

NOTE: When further adjustment DOES NOT increase the signal amplitude, but DOES increase the noise level, back off on the control until the signals are just maximum amplitude.

c. PPI and range strobe adjustments.

(1) On the SIGNAL COMPARATOR, set OPERATION SELECTOR switch S2354 to REMOTE.

(2) On the INDICATOR, set SYSTEM SELECTOR switch S601 to NORMAL.

(3) Turn RECEIVER GAIN control R608 fully counterclockwise.

(4) Set PPI SWEEP SELECTOR switch S606 to 160 miles.

(5) Set RANGE MARKER switch S608 to ON.

(6) Set PPI VIDEO GAIN control R682 fully counterclockwise.

(7) Set PPI INTENSITY control R659 to approximately midposition.

(8) Adjust COARSE INTENSITY control R660A and B (ganged), until the PPI baseline just disappears from the screen, then lock R660 in position.

(9) Adjust INTENSITY control R659 until the baseline just begins to appear on the screen.

(10) Adjust FOCUS control R671 for a sharply focused baseline.

(11) Adjust PPI SWEEP LENGTH control R651 so that the complete baseline will continually be on the screen from the center to the outer edge.

(12) Set PPI SWEEP SELECTOR switch S606 to 40 miles.

(13) Adjust 5-10 MILE MARKER INTENSITY control R1617 for distinct range markers on the baseline.

(14) Set PPI SWEEP SELECTOR switch S606 to 160 miles.

(15) Adjust 25-MILE MARKER INTENSITY control R1629 for distinct range markers on the baseline.

(16) While holding RANGE MARKER switch S608 in the TEST position, adjust PPI GATE control R626 so that the baseline displays 160 miles as indicated by the range markers.

(17) Rotate the antenna and check the centering of the baseline.

(18) If the baseline does not start at the center of the screen, adjust PPI CENTERING controls R662 and R665.

(19) Set RANGE MARKER switch S608 to ON.

(20) Rotate the antenna.

(21) Adjust PPI SWEEP LENGTH control R651 to insure that the range markers are visible throughout complete rotation of the baseline around the face of the screen.

(22) Recheck for a properly centered baseline.

(23) Set RANGE MARKER S608 switch to OFF.

(24) Adjust RANGE STROBE INTENSITY control R685 until the range strobe is clearly visible on the baseline.

(25) Turn RANGE STROBE POSITION control R1657 fully clockwise.

(26) Adjust TRIGGER (STROBE LIMITER ADJUST) control R1655 so that the strobe is at 160 miles of range on the baseline.

(27) Observe the A-scope and adjust RECEIVER GAIN control R608 for approximately one-quarter inch of grass.

(28) Rotate the antenna and, while observing the PPI, adjust PPI VIDEO GAIN control R682 until the echo signals produce a slightly milky background on the screen.

(29) Recheck the INTENSITY and FOCUS controls.

d. Azimuth orientation.

(1) Determine the correct azimuth to the most distant visible fixed object.

(2) Position the antenna until this object appears as a maximum fixed echo on the PPI screen.

(3) Adjust AZIMUTH CONTROL until the PPI baseline indicates the correct azimuth of the fixed echo on the azimuth scale on the outer edge of the PPI.

(4) Slide the INDICATOR back into its case and secure the holding bolts.

Section III. SUMMARY AND QUESTIONS

73. SUMMARY

a. The half-wave rectifier V626 provides the high voltage for the scope operation in the indicator. The plate circuit of V626 gives the negative potentials for the A-scope, and the cathode circuit develops the positive aquadag voltages for both scopes as well as the accelerating voltage for the PPI. Both the negative and positive supply can be monitored for a measurable dc voltage potential. The loss of the high-voltage power is noted by a complete removal of the electron stream on both scopes.

b. The field adjustments are the logical procedure of the complete indicator adjustment. They must be understood to where it is possible to adjust only needed controls for operation.

74. QUESTIONS

a. What is the purpose of C666 and C665?

b. Is the high-voltage rectifier designed for a high or low current drain?

c. Where is the only safe place to measure the high-voltage power supply outputs?

d. What is the noted symptom if V626 is inoperative?

e. What would be the result on the +5,000-volt supply if the reading at TP612 were 135 volts?

f. Do the A-scope and PPI GATE controls R1669 and R626 vary the electrical or the physical lengths of the sweeps?

g. If the range markers appear on the A-scope screen in a leaning position, what is the needed adjustment?

h. Can the amplitude of the range markers on the A-scope screen be varied?

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